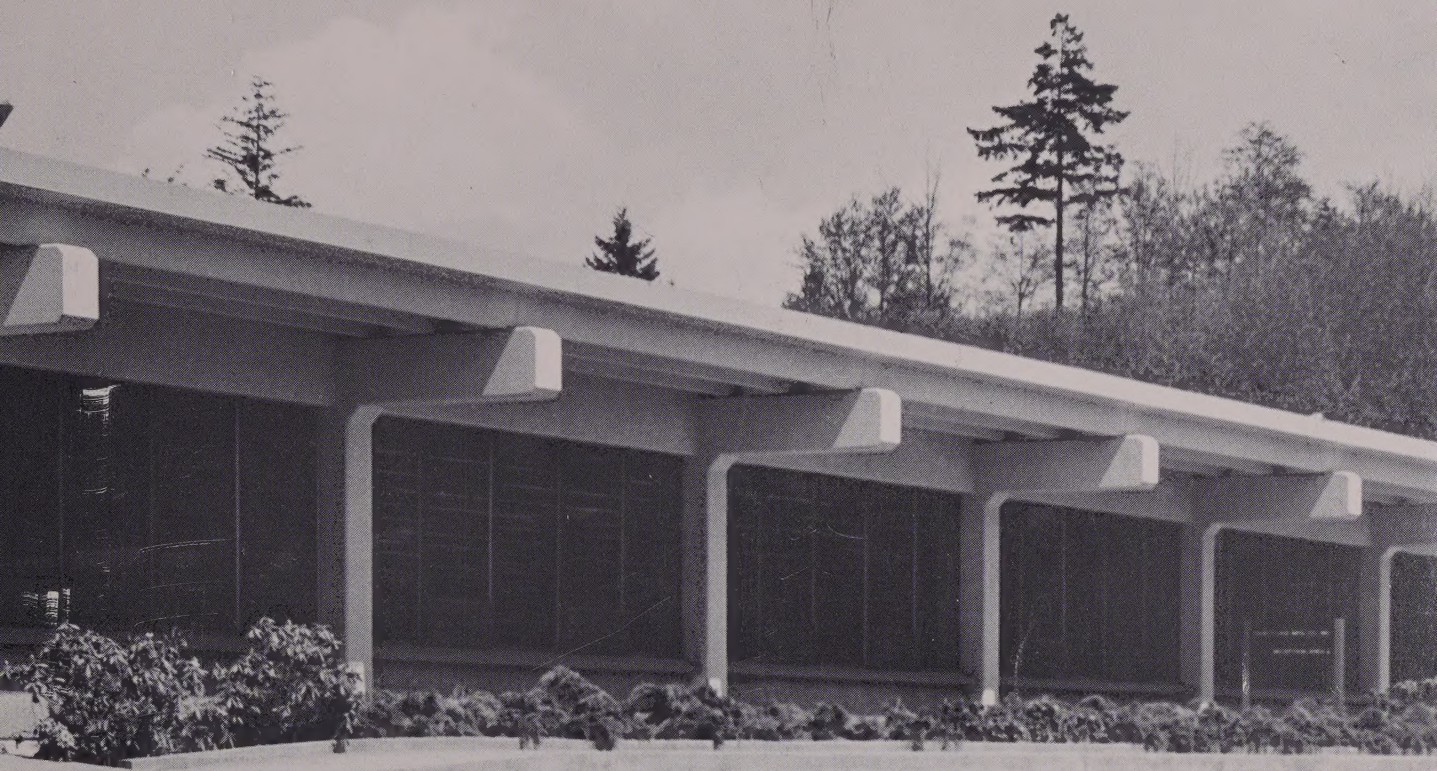
M21

Instruction Manual



DIGITAL OUTPUT OPTION

MODEL

2160A

FLUKE®

JOHN FLUKE mfg. co., inc.
SEATTLE, WASHINGTON

JOHN FLUKE MFG. CO., INC.

P. O. Box 43210
Mountlake Terrace, Washington 98043

DIGITAL OUTPUT OPTION

MODEL

2160A

DIGITAL THERMOMETER

P/N 445429
APRIL 1976

WARRANTY

The JOHN FLUKE MFG. CO., INC.* warrants each instrument manufactured by them to be free from defects in material and workmanship. Their obligation under this Warranty is limited to servicing or adjusting an instrument returned to the factory for that purpose, and to making good at the factory any part or parts thereof; except tubes, fuses, choppers and batteries, which shall, within one year after making delivery to the original purchaser, be returned by the original purchaser with transportation charges prepaid, and which upon their examination shall disclose to their satisfaction to have been thus defective. If the fault has been caused by misuse or abnormal conditions of operations, repairs will be billed at a nominal cost. In this case, an estimate will be submitted before work is started, if requested.

If any fault develops, the following steps should be taken:

1. Notify the John Fluke Mfg. Co., Inc.,* giving full details of the difficulty, and include the Model number, type number, and serial number. On receipt of this information, service data or shipping instructions will be forwarded to you.

2. On receipt of the shipping instructions, forward the instrument prepaid, and repairs will be made at the factory. If requested, an estimate will be made before the work begins, provided the instrument is not covered by the Warranty.

"The foregoing warranty is in lieu of all other warranties, express or implied, including but not limited to, any implied warranty of merchantability, fitness or adequacy for any particular purpose or use. Fluke shall not be liable for any special, incident or consequential damages."

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CLAIM FOR DAMAGE IN SHIPMENT

The instrument should be thoroughly inspected immediately upon receipt. All material in the container should be checked against the enclosed packing list. The manufacturer will not be responsible for shortages against the packing sheet unless notified immediately. If the instrument fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report should be forwarded to John Fluke Mfg. Co., Inc.* Upon receipt of this report, you will be advised of the disposition of the equipment for repair or replacement. Include the model number, type number, and serial number when referring to this instrument for any reason.

The John Fluke Mfg. Co., Inc.* will be happy to answer all application questions which will enhance your use of this instrument. Please address your requests to: JOHN FLUKE MFG. CO., INC., P.O. Box 43210, MOUNTLAKE TERRACE, WASHINGTON 98043*.

* For European customers: FLUKE (Nederland) B.V.
Ledeboerstraat 27
Tilburg, Netherlands

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FLUKE TECHNICAL SERVICE CENTERS

Fluke Western Technical Center
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Burbank, CA 91504
Tel. 213-849-4641
TWX: 910-497-2086

Fluke Western Technical Center
4805 Mercury St.
San Diego, CA 92111
Tel. 714-565-4455
TWX: 910-337-1273

Fluke Western Technical Center
2359 De La Cruz Blvd.
Santa Clara, CA 95050
Tel. 408-244-1505
TWX: 910-338-0121

Fluke S.W. Technical Center
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1980 South Quebec Street
Denver, CO 80231
Tel. 303-750-1228
TWX: 910-320-2263

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Orlando, FL 32803
Tel. 305-896-2296
TWX: 810-850-0185

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TWX: 910-233-4978

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Tel. 301-881-5300
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Calgary, Alberta
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Fluke Canadian Technical Center
6427 Northam Drive
Mississauga, Ontario
Tel. 416-678-1500
TWX: 610-492-2119

Rev. 11/75

CERTIFICATE of CALIBRATION

The John Fluke Mfg. Co., Inc. hereby certifies that this instrument meets or exceeds all published specifications and has been calibrated using standards whose accuracies are traceable to the National Bureau of Standards within the limitations of the Bureau's calibration services, or have been derived from accepted values of natural physical constants, or have been derived by the ratio type of self-calibration techniques.

Applicable NBS Test Reports:

DC Voltage – 213385

AC Voltage – 212126 & 807675

Resistance – 210508

John F. Holloran

STANDARDS ENGINEER

A. J. Petrobe

MANAGER QUALITY ASSURANCE

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CHANGE/ERRATA INFORMATION

MANUAL — TITLE: DIGITAL THERMOMETERS
2160A, 2170A, 2165A, 2175A, 2166A, 2176A, 2168A
ISSUE: APRIL 1976

Please make changes in this manual according to the following change and/or errata information:

ERRATA

In each of the instruction manuals listed below, add the following warning prior to paragraph 2-1, in Section 2. Insert the appropriate paragraph numbers (given below) in the space provided in the warning.

INSTRUCTION MANUAL	PARAGRAPHS
2160A	2-17, 2-21 and 2-23
2170A	2-17, 2-21 and 2-23
2165A	2-17 and 2-21
2175A	2-17 and 2-21
2166A	2-21 and 2-27
2176A	2-21 and 2-27
2168A	2-21

Insert appropriate paragraph nos.

WARNING!

Due to the possible presence of lethal voltages, the procedure(s) in paragraph(s) _____ should be performed by qualified personnel only.

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Section 1
Introduction & Specifications

1-1. INTRODUCTION

1-2. The Model 2160A Digital Thermometer is a panel-mounting, four-digit, thermocouple thermometer capable of resolving 1°C or 1°F over a temperature range of −200 to +2328°C or −328 to +3999°F. It features a four digit LED display, a reference-junction compensator (to eliminate the need for an ice bath reference junction), front-panel jumper selection of °C or °F, the choice of using any one-of-eight thermocouples types (J, K, E, T, R, S, B or C) as the input device, dual-slope measurement techniques and digital linearization of the thermocouple inputs. Several options and accessories are also available for use with the 2160A.

1-3. The front panel display consists of five, seven-segment, high-intensity LED's, and features leading-zero suppression. Four of the LED's are used to display numeric data, including a minus sign for negative temperature indications. The fifth LED displays the selected °C or °F scale character. An open-thermocouple detector causes the display to blink when an open circuit is sensed at the thermocouple input terminals.

1-4. Rear-panel, screw-type input connectors are provided for attaching the selected thermocouple. These terminals are an integral part of an isothermal block, and serve as the reference-junction for the reference-junction compensator. (The reference-junction compensator provides the physical and electrical equivalent of, and eliminates the need for, an ice bath reference junction at 0°C or 32°F.)

1-5. A jumper located behind the display lens can be positioned to select either the °C or °F temperature scale. The scale change can be made at any time and has no affect on calibration. The °C or °F LED displays the selected scale.

1-6. The actual measurement range of the 2160A is determined by the type of thermocouple being used as the input device. Any one-of-eight thermocouple types can be used; J, K, E, T, R, S, B or C. To ensure the proper linearization of the selected thermocouple input, a corresponding linearization program must be selected on the interior of the unit. Selection is accomplished by installing a type select pcb which corresponds to the input thermocouple. A single type select pcb is supplied with the unit to match the thermocouple type specified at the time of purchase. The remaining PCB's are individually available as accessories and are described in Table 1-1.

Table 1-1. 2160A ACCESSORIES

MODEL NO.	DESCRIPTION
P20J	J-Type Thermocouple Probe
P20K	K-Type Thermocouple Probe
P20T	T-Type Thermocouple Probe
M00-200-611	Rack Mounting Kit, Offset
M00-200-612	Rack Mounting Kit, Center
2160A-7031	Rack Mounting Panel, one unit
2160A-7032	Rack Mounting Panel, two units
2160A-7033	Rack Mounting Panel, three units
2160A-7016	J-Type Select PCB
2160A-7017	K-Type Select PCB
2160A-7019	E-Type Select PCB
2160A-7018	T-Type Select PCB
2160A-7012	R-Type Select PCB
2160A-7013	S-Type Select PCB
2160A-7014	B-Type Select PCB
2160A-7015	C-Type Select PCB
2160A-7022	Interface Cable
2161A	Multipoint Selector
2162A	Digital Comparator

1-7. Options available for use with the 2160A are listed and described in Table 1-2. Both options are field installable. Either one, but not both, of the options can be installed in a unit. Detailed information concerning each option is given in Section 6 of this manual, Option and Accessory Information.

Table 1-2. 2160A OPTIONS

OPTION NUMBER	DESCRIPTION
–02	Analog Output Unit
–04	Digital Output Unit

1-8. The 2160A is available in any one-of-three line power configurations: 100V ac, 50 to 440 Hz; 115V ac, 50 to 440 Hz; and 230V ac, 50 to 440 Hz. Specify the required configuration at the time of purchase.

1-9. SPECIFICATIONS

1-10. Specifications for the 2160A are given in Table 1-3.

Table 1-3. SPECIFICATIONS

ELECTRICAL

Compatible Thermocouple Types	Unit can be calibrated to operate with any one of the following thermocouple types: J, K, T, E, R, S, B or C
Measurement Method	Dual-slope integration over a 100 ms period.
Zero Drift	None. Automatic zero correction.
Reading Rate	2.5 readings per second
°C to °F Conversion	Jumper selectable
Input Characteristics	
Input Connections	Screw terminals on isothermal connector
Input Circuit	Two-wire, isolated
Input Impedance	$> 100\ M\Omega$
Input Current	< 500 pA
Source Impedance	$\leq 5k\Omega$. $5k\Omega$ causes $< 0.2°C$ error with k thermocouple.
Overload	Display flashes when input voltage exceeds full-scale temperature range.
Open Input	Display flashes to indicate open at input terminals.
Maximum Input Voltage (without damage)	400V dc or ac peak continuously between inputs or either input and ground.
Maximum Common Mode Voltage (without damage)	400V dc or ac peak.
Common Mode Rejection	$\geq$ 120 dB @ 50, 60, 400 Hz $\pm$0.1% with $1k\Omega$ source impedance unbalance.
Normal Mode Rejection	$\geq$ 60 dB @ 50, 60, 400 Hz $\pm$0.1%
Accuracy	See Table 1 for °C specifications and Table 2 for °F specifications.
Response Time to Rated Accuracy	< 2.0 seconds
Linearization	Digital with eight selectable programs in LSI ROM.
Linearization Programs	
J, K, T and E	32 straight line segments for positive inputs and 16 for negative inputs.
R, S, B and C	48 straight line segments for positive inputs.

Table 1-3. SPECIFICATIONS (Cont.)

Reference Junction Compensation

20 to 30°C

J, K, T, E	0.025 degrees per degree
R, S	0.05 degrees per degree
C	0.02 degrees per degree

0 to 20°C, 30 to 50°C

J, K	0.032 degrees per degree
T, E	0.045 degrees per degree
R, S	0.07 degrees per degree
C	0.04 degrees per degree

Temperature Coefficient . . . . . 0.005% of reading per °C

Internal Temperature Rise . . . . . ⩽5°C

Table 1 ACCURACY SPECIFICATIONS °C

THERMOCOUPLE TYPE	TEMPERATURE RANGE °C	RESOLUTION AND REPEATABILITY (±°C)	APPLICABLE TEMPERATURE RANGE °C	MAXIMUM ERROR INCLUDING NBS CONFORMITY (±°C)				NBS CONFORMITY (±°C)
				CALIBRATION ACCURACY	20 min. to 24 hrs. 23 to 27°C	90 Days 20 to 30°C	1 Year 15 to 35°C	
J	–200 to 778	1	–200 to 0 0 to 778	1 1	1 1	1.5 1	1.5 1.5	.19 .15
K	–200 to 1356	1	–200 to 0 0 to 1356	1 1	1 1	1.5 1.5	2 2	.20 .18
T	–200 to 400	1	–200 to 0 0 to 400	1 1	1 1	1.5 1	2 1	.19 .15
E	–200 to 1000	1	–200 to 0 0 to 1000	1 1	1 1	1.5 1	2 1.5	.17 .18
R	0 to 1778	1	0 to 1778	1.5	1.5	2.5	3	.26
S	0 to 1778	1	0 to 1778	1.5	1.5	2	3	.22
B	533 to 1844	1	533 to 1844	1.5	1.5	2	2.5	.29
C	0 to 2328	1	0 to 2328	2.5	2.5	3.5	4	.71

*Includes reference junction and conformity errors. Excludes thermocouple errors.

Table 1-3. SPECIFICATIONS (Cont.)

Table 2 ACCURACY SPECIFICATIONS °F

THERMOCOUPLE TYPE	TEMPERATURE RANGE °F	RESOLUTION AND REPEATABILITY (±°F)	APPLICABLE TEMPERATURE RANGE °F	MAXIMUM ERROR INCLUDING NBS CONFORMITY (±°F)				NBS CONFORMITY (±°F)
				CALIBRATION ACCURACY	20 min. to 24 hrs. 72 to 82°F	90 Days 68 to 86°F	1 Year 59 to 95°F	
J	–328 to 1432	1	–328 to 32 32 to 1432	1.5 1	1.5 1	2 1.5	2.5 2	0.27 0.2
K	–328 to 2472	1	–328 to 32 32 to 2472	2 1.5	2 1.5	2.5 2.5	3 3	0.28 0.26
T	–328 to 752	1	–328 to 32 32 to 752	1.5 1	1.5 1	2 1.5	3.5 2	0.3 0.2
E	–328 to 1832	1	–328 to 32 32 to 1832	1.5 1	1.5 1.5	2 2	3.5 2.5	0.25 0.25
R	32 to 3232	1	32 to 3232	2	2.5	4	5	0.4
S	32 to 3232	1	32 to 3232	2	2.5	3.5	4.5	0.33
B	992 to 3352	1	992 to 3352	2	2.5	3.5	4.5	0.45
C	32 to 3999	1	32 to 3999	4	4.5	6	6.5	1.24

*Includes reference junction and conformity errors. Excludes thermocouple errors.

GENERAL

Type of Display . . . . . LED, 0.56 in high.

Power Requirements . . . . . 115V ac ± 10%, 50 to 440 Hz, 4W. 100V ac and 230V ac versions are also available.

Size . . . . . 1.88 in (H) x 3.78 in (W) x 8.05 in (D) (4.78 cm x 9.6 cm x 20.45 cm). Conforms to DIN standard. See Figure 1-1.

Weight . . . . . 1 lb. 10 oz. (0.737 kg)

ENVIRONMENTAL

Temperature

Operating . . . . . 0 to 50°C (32 to +122°F)

Storage . . . . . –40 to 75°C (–40 to 167°F)

Humidity

0 to 50°C . . . . . 80% non-condensing

0 to 35°C . . . . . 90% non-condensing

Shock and Vibration . . . . . Meets requirements of MIL Standard 810

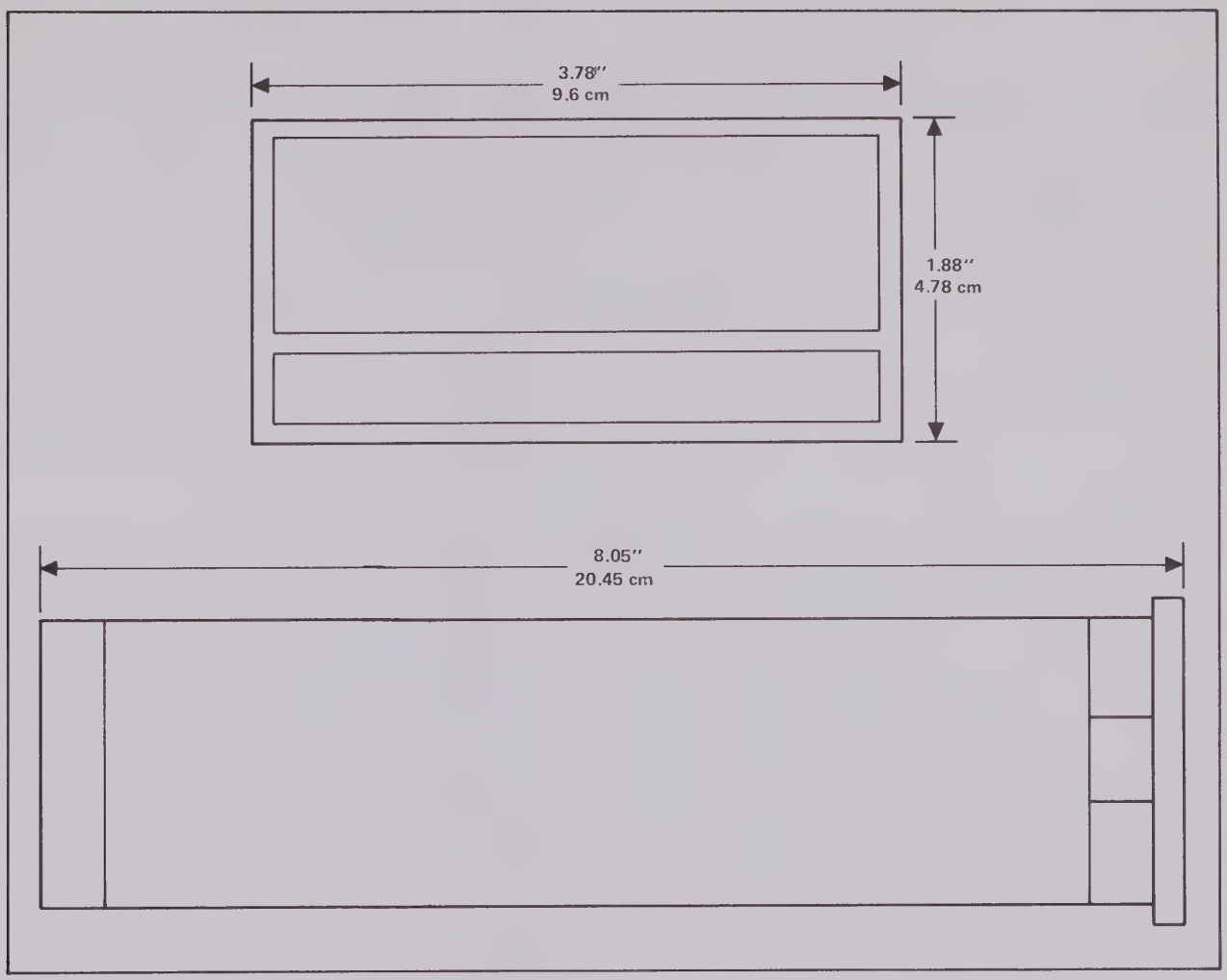


Figure 1-1. 2160A OUTLINE DRAWING

Section 2
Operating Instructions

2-1. INTRODUCTION

2-2. This section of the manual contains information regarding installation and operation of the Model 2160A Digital Thermometer. It is recommended that the contents of this section be read and understood before any attempt is made to operate the instrument. Should any difficulties arise during operation, please contact your nearest Fluke Technical Service Center, or the John Fluke Mfg. Co., Inc. P.O. Box 43210, Mountlake Terrace, WA 98043, Tel (206) 774-2211. A list of Technical Service Centers is located in Section 7 of this manual.

2-3. SHIPPING INFORMATION

2-4. The 2160A is packaged and shipped in a foam-packed container. Upon receipt of the instrument, a thorough inspection should be made to reveal any possible shipping damage. Special instructions for inspection and claims are included in the shipping carton.

2-5. If reshipment of the instrument is necessary, the original container should be used. If the original container is not available, a new one can be obtained from the John Fluke Mfg. Co., Inc. Please reference the instrument model number when requesting a new shipping container.

2-6. INPUT POWER

2-7. The 2160A is factory wired to operate from one-of-three ac line voltages. These are: 100V ac, 50 to 440 Hz; 115V ac, 50 to 440 Hz; and 230V ac, 50 to 440 Hz. Before connecting the 2160A to the ac line, check to ensure that the instrument is wired to accommodate the local line voltage. A decal on the rear of the unit defines the particular line voltage required to operate the instrument.

2-8. The rear panel ac input connector is a three-prong, U-ground connector which permits the instrument to be connected, via the power cord, to the appropriate line voltage. The offset prong on this connector is connected to the 2160A power supply, and should be connected through the power cord to a high quality earth ground.

2-9. PANEL INSTALLATION

2-10. The 2160A is designed for installation in a console panel. The panel-mounting feature is an integral part of the instrument and does not require the use of a panel mounting kit. The unit conforms to DIN standards and will accommodate a panel thickness ranging from one-sixteenth of an inch to one-quarter of an inch. Use the following procedure to panel-mount the 2160A:

a. Locate the mounting position on the panel and cut a 1.722 inch-by-3.622 inch (4.374 cm x 9.2 cm) rectangular hole.

b. Remove the red, plastic display cover from the 2160A. Lift the cover at the bottom-center with a screw driver and continue to bow the cover until it pops out.

c. Locate the two screws on either side of the bezel and turn them ccw until their cam nuts are their rear-most position.

d. Slide the power cord and thermocouple (if attached) through the front-side of the prepared panel hole.

e. Slide the 2160A into the panel hole (back-side first) until its bezel is flush with the panel. Make sure the cam nuts are inside their recesses during this procedure.

f. Hold the 2160A firmly against the panel, and turn both side panel screws cw until they are snug. Do not apply excessive pressure. If the procedure was executed properly, the cam nuts should be extended behind the panel and the instrument should be firmly held in place.

g. Place one side of the plastic display cover into position on the 2160A (frosted side out) and, bowing the cover away from the instrument, snap the other side into position.

2-11. OPERATING FEATURES

2-12. The location of all 2160A controls, indicators and connectors are shown in Figure 2-1, and described in Table 2-1.

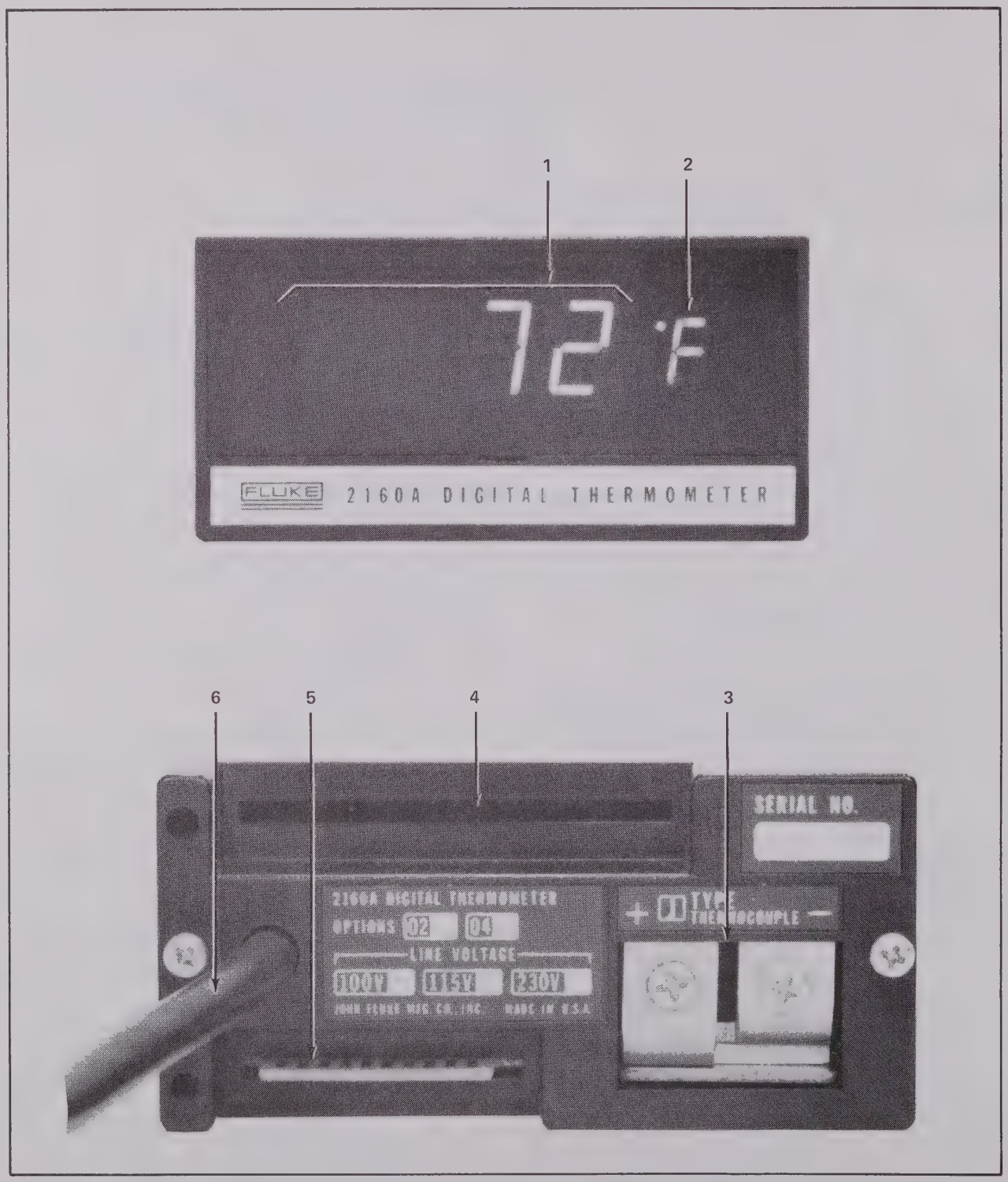


Figure 2-1. 2160A CONTROLS, INDICATORS AND CONNECTORS

Table 2-1. 2160A CONTROLS, INDICATORS AND CONNECTORS

REF. NO.	NAME	FUNCTION
1	Digital Display	Displays a four digit readout of the measured input temperature. Leading-zero suppression is also included. A minus sign is displayed for negative temperature measureemnts. The absence of a polarity sign indicates a positive temperature measurement.
2	Temperature Scale Indicator	Displays the temperature scale represented by the digital display data; °C or °F.
3	Thermocouple Input Connections	Provides screw-type terminals for connecting the thermocouple to the thermometer.
4	AOU/DOU I/O Port	Provides external access to the card-edge connector of the Digital Output Unit (Option –02) or the Analog Output Unit (Option –04), when installed.
5	Digital Comparator Connector	Provides the card-edge connections necessary to interface the 2160A with one or more 2162A Digital Comparators. See Section 6 of this manual for details concerning the 2162A.
6	Input Power Cable	Provides the means of connecting the instrument to ac line power.

2-13. OPERATING NOTES

2-14. The following paragraphs describe various conditions which should be considered before operating the 2160A.

2-15. Option Information

2-16. Supplementary operating instructions are necessary when operating a 2160A which is equipped with one of the available options. Detailed information regarding the operation of each available option is given in Section 6 of this manual, Option and Accessory Information.

2-17. Fuse Replacement

2-18. The ac line-input section of the 2160A power supply is fuse protected. The fuse is located on the interior of the unit near the power transformer. To access the fuse, disconnect the 2160A from line power, remove the rear-panel retaining screws located on both sides of the rear panel, and pull the pcb out the rear of the chassis. When replacement is necessary, use an AGC 1/16A fuse.

2-19. Overload and Open Thermocouple Indication

2-20. The front panel display, in addition to providing a measurement reading, is designed to serve as an overrange or open thermocouple indicator. When the measurement range of the input thermocouple is exceeded, or when the thermocouple inputs are open circuited, the display will blink. The blinking indication does not mean that the instrument is being exposed to a damaging input condition.

2-21. Temperature Scale, °C or °F

2-22. The 2160A temperature scale can be selected from the front panel for direct readings in °C or °F. The desired scale is selected by positioning a jumper located behind the red-plastic display cover. Use the following procedure to change temperature scales:

NOTE

When the 2160A is energized the selected temperature scale is displayed at the right of the readout.

a. Remove line power from the instrument.

b. Remove the red-plastic display cover from the 2160A. Lift the cover at the bottom center with a screw driver and continue to bow the cover until it pops out.

c. Locate the °C/°F jumper on the Display PCB as shown in Figure 2-2.

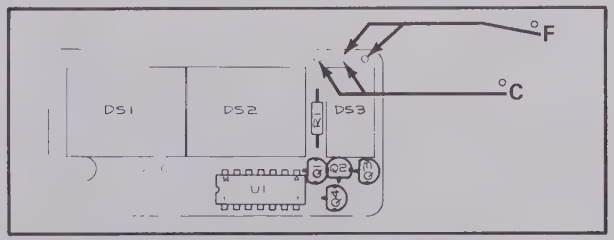


Figure 2-2. TEMP. SCALE (°C/°F) JUMPER LOCATION

d. Remove the jumper using a pair of long nose pliers, and install it in the desired °C or °F position.

e. Place one side of the plastic display cover into position on the 2160A (frosted side out) and, bowing the cover away from the instrument, snap the other side into position.

e. Energize the 2160A. The selected temperature scale should be displayed.

2-23. Thermocouple Compatibility

2-24. The 2160A is designed to operate in conjunction with a selected type of thermocouple probe. A decal on the rear of the unit identifies the compatible thermocouple type. When necessary, the 2160A can be modified in the field to accommodate any one of the following thermocouple types: J, K, E, T, R, S, B or C. Use the following procedure to change thermocouple type:

a. Refer to Table 1-1 in Section 1 of this manual and order the type select pcb which corresponds to the desired thermocouple type. These pcbs are low cost items and can be purchased from any of the John Fluke Technical Service Centers (See Section 7) or from the John Fluke Mfg. Co., Inc.

b. Disconnect the 2160A from line power.

c. Remove any ribbon-cable connectors that may be attached to the rear of the 2160A.

d. Remove the screws on both sides of the rear panel, and slide the panel away from the unit.

e. Grasp the thermocouple input connectors and carefully pull the pcb (s) out of the chassis.

f. Unplug and remove the currently installed type select pcb from the position shown in Figure 2-3, and install the new one in its place.

NOTE

The thermocouple type is etched on the type select pcbs. When properly installed the arrows on the pcb point toward the digital display.

g. Install the 2160A pcb in its chassis and secure the rear panel using the two side-center screws.

h. Connect the new type thermocouple to the thermocouple input terminals.

i. Place a piece of tape over the rear panel thermocouple type decal, and inscribe the new thermocouple type on it.

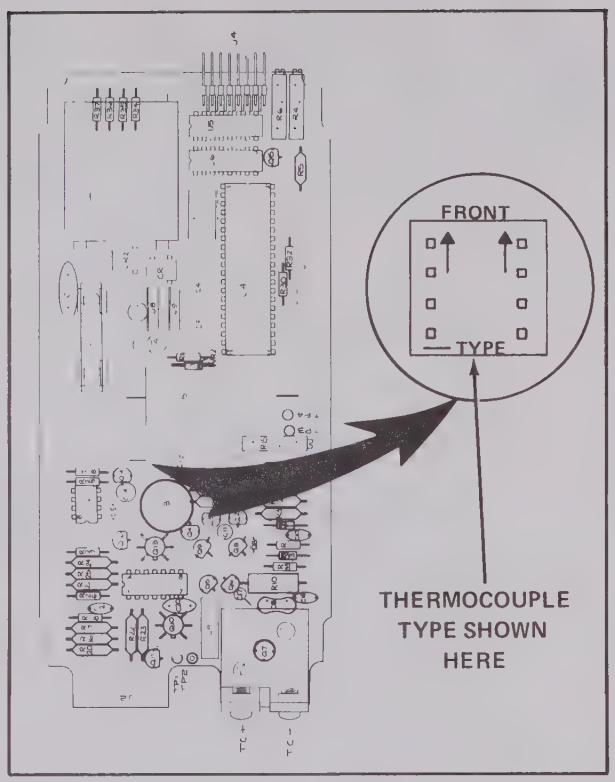


Figure 2-3. TYPE SELECT PCB, LOCATION AND INSTALLATION DETAILS

j. Connect the unit to line power, and complete the routine calibration procedure given in Section 4 (Maintenance) of this manual.

2-25. OPERATION

2-26. With reference to previous paragraphs in this section, operate the 2160A as follows:

a. Refer to the rear-panel decal and connect a compatible thermocouple probe to the thermocouple input terminals. Observe polarity shown on decal.

b. Select the desired temperature scale (°C or °F) using the procedure given earlier.

c. Energize the instrument by connecting the power cord to the appropriate ac line power as defined on the rear-panel decal.

d. Refer to Section 6 of this manual for instructions concerning the operation of the –02 and –04 options.

e. Expose the thermocouple probe to a temperature within its specified range (see Specifications in Section 1). The probe temperature will be displayed on the front panel.

Section 3
Theory of Operation

3-1. INTRODUCTION

3-2. This section of the manual contains an overall functional description followed by a circuit analysis of the 2160A. Simplified circuit diagrams and timing diagrams are included, as necessary, to supplement the text. Detailed schematics are given in Section 8 of this manual.

3-3. OVERALL FUNCTIONAL DESCRIPTION

3-4. The Model 2160A Digital Thermometer, as shown in Figure 3-1, is a four-digit, thermocouple thermometer capable of resolving 1°C or 1°F over a temperature range of −200 to +2328°C or −328 to +3999°F. It features a reference junction compensator (to eliminate the need for an ice-bath reference junction), dual-slope integration, LSI digital control logic (includes linearization programs for J, K, E, T, R, S, B and C type thermocouples), and a four-digit LED display.

3-5. In operation, the 2160A executes a continuous series of measurement cycles to update the temperature display. The measurement cycle is controlled entirely by an LSI digital IC, and includes three major subcycles; Auto-Zero period, Integrate period and Read period. Each subcycle controls the operation of the analog section of a dual-slope integrator which, in turn, generates a compare output to control the digital conversion performed by the LSI digital IC.

3-6. The configuration of the analog section of the 2160A, during each phase of the measurement cycle, is established by a combination of FET switches that are controlled by the LSI digital IC. The measurement cycle begins with the Auto-Zero period. During this period, the reference junction compensation voltage and the accumulated dc offset voltages present in the analog section are sampled and held by capacitors. These voltages are used later in the measurement cycle to cancel measurement errors introduced by offset voltages and reference junction voltage errors created at the input

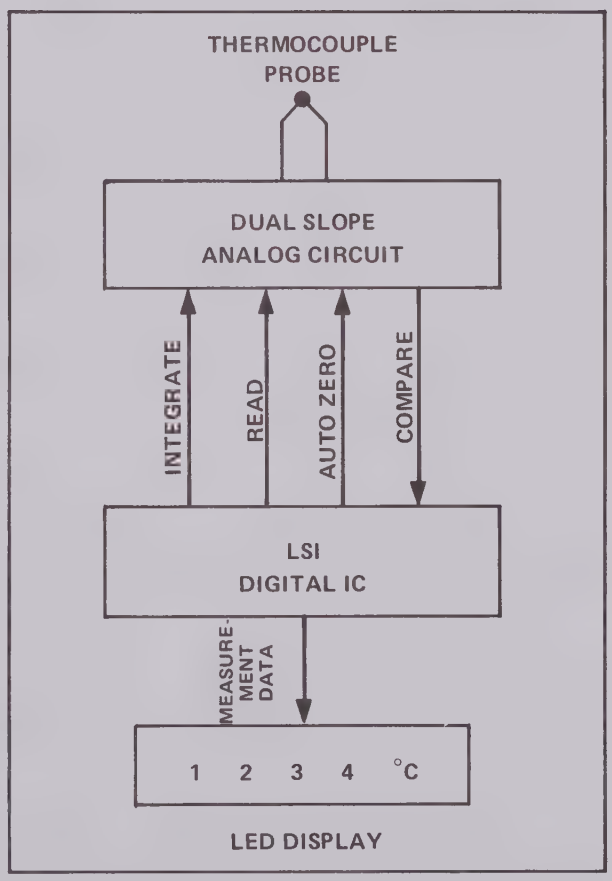


Figure 3-1. 2160A SIMPLIFIED BLOCK DIAGRAM

terminal connections. As a result, the final measurement is proportional to the thermocouple probe output voltage and does not include offset errors or reference junction voltage errors. During the Integrate period, the thermocouple input voltages (probe voltage and input terminal voltages) are applied to the integrator, and the algebraic sum of these voltages is integrated over a 100 ms period. At the end of this period, the thermocouple input voltages are removed from

the integrator and the Read period is started. A reference voltage is applied to the integrator during the Read period causing the integrator capacitor to be discharged at a linear rate. When the integrator output reaches zero, a compare signal is generated to end the Read period. The duration of the Read period is translated by the LSI digital IC to provide a digital indication proportional to the thermocouple probe temperature.

3-7. CIRCUIT ANALYSIS

3-8. Circuit analysis of the 2160A is discussed in two sections; digital and analog. The digital section is covered first, and particular attention is paid to the control it exercised on the analog section. The analysis of the analog section covers the analog measurement circuitry and the 2160A power supply.

3-9. Digital Section

3-10. The digital section of the 2160A consists of an LSI digital IC, a hex buffer, a seven-segment decoder/driver and an LED display. Its function is to convert the non-linear thermocouple probe voltage, as measured by the analog section, into a linear digital display. The display provides a direct reading of probe temperature in °C or °F.

3-11. The LSI digital IC contains all of the 2160A control logic and linearizing capability, and provides the hex buffer and seven-segment decoder with the data necessary to update the LED display. The linearization of the nonlinear input signal is accomplished by selecting one-of-eight programs which vary the rate at which the measurement counts are accumulated. The program is selected to match a particular thermocouple type. Program selection is accomplished by a series of plug-in type select pcb's which are available as accessories.

3-12. Measurement data is continuously strobed out of the LSI digital IC in bcd, character-serial format. At the end of each measurement cycle, an update flag is raised to signify that a new reading is available. When an overload occurs, the number of accumulated counts are stored and presented, along with a blanking pulse, as output data. The blanking pulse alternately turns the display on and off to indicate the presence of an overload.

3-13. The basic measurement cycle, as shown in Figure 3-2, comprises three subcycles; a 100 ms minimum Auto-Zero period, a 100 ms Integrate period, and a variable Read period. The auto-zero period is extended to 300 ms when an overload occurs. To accommodate settling times in the analog section, a 500 us hold signal is inserted at the beginning and at the end of the Integrate period.

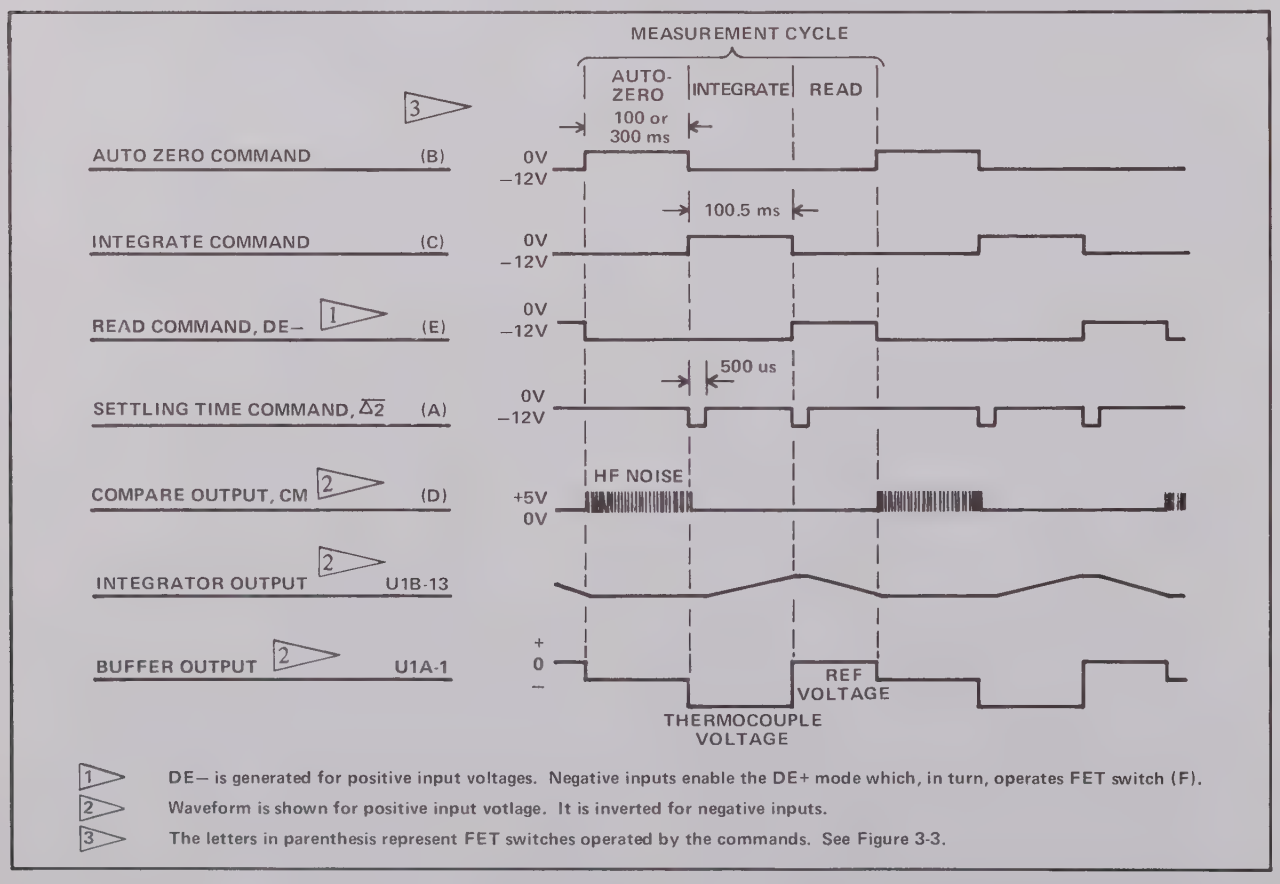

MEASUREMENT CYCLE
AUTO-ZERO
INTEGRATE
READ
100 or 300 ms
100.5 ms
500 us
AUTO ZERO COMMAND (B)
INTEGRATE COMMAND (C)
READ COMMAND, DE– (E)
SETTLING TIME COMMAND, Δ2 (A)
COMPARE OUTPUT, CM (D)
INTEGRATOR OUTPUT U1B-13
BUFFER OUTPUT U1A-1
0V
–12V
+5V
HF NOISE
REF VOLTAGE
THERMOCOUPLE VOLTAGE
1 DE– is generated for positive input voltages. Negative inputs enable the DE+ mode which, in turn, operates FET switch (F).
2 Waveform is shown for positive input votlage. It is inverted for negative inputs.
3 The letters in parenthesis represent FET switches operated by the commands. See Figure 3-3.

Figure 3-2. MEASUREMENT CYCLE WAVEFORMS

3-14. Analog Section

3-15. ANALOG MEASUREMENT CIRCUIT

3-16. The analog measurement circuit is shown in simplified form in Figure 3-3. It consists of a thermocouple input circuit, a reference-junction compensator, a voltage reference, a Buffer Amplifier, an Integrator, a Comparator, and a combination of FET switches. The switches are shown in their open state and are closed by the measurement cycle commands generated by the LSI digital IC. Each switch is assigned a letter designation which corresponds to a measurement cycle command shown in Figure 3-2.

3-17. The Thermocouple Input circuit consists of an R-C filter and a pair of voltage protection diodes. The difference between the thermocouple probe voltage and the input terminal voltage is passed through the filter and appears at the arm of switch C.

3-18. The Reference-Junction Compensator consists of an isothermal block, a pair of screw type input terminals, and a transistor temperature sensor. The isothermal block maintains a known temperature differential between the input terminals and the temperature sensing transistor. Thermocouple voltages introduced by the dissimilar metals at the input terminals vary as the isothermal block adjusts to ambient temperature. Temperature changes are sensed by the forward-biased transistor which produces a correction voltage equivalent to the thermocouple voltage created at the input terminals. Predictable characteristics of a forward-biased P-N junction allow the Reference-Junction Compensator to function over a wide temperature range. The correction voltage is matched to the thermocouple probe type by a selected Offset Resistor which is supplied on a plug-in type select pcb. The correction voltage appears at the arm of switch B1.

3-19. The voltage reference consists of a resistor divider which is supplied by an accurate 6.4V dc reference voltage. The divider is calibrated to match the thermocouple probe type by a selected resistor on the plug-in type select pcb. Two voltages are available at the divider outputs; 0.5 x V ref, and 1.5 x V ref. These voltages appear at the arms of switches B2 and E, respectively.

3-20. The Buffer, Integrator and Comparator amplifiers combine to perform the analog functions of the Integrate, Read and Auto-Zero periods. The Buffer is used to provide integrator inputs during all three periods. The Integrator integrates the Buffer output voltage during the Integrate and Read periods, and functions, in combination with the Comparator, as a closed-loop amplifier during the Auto-Zero period.

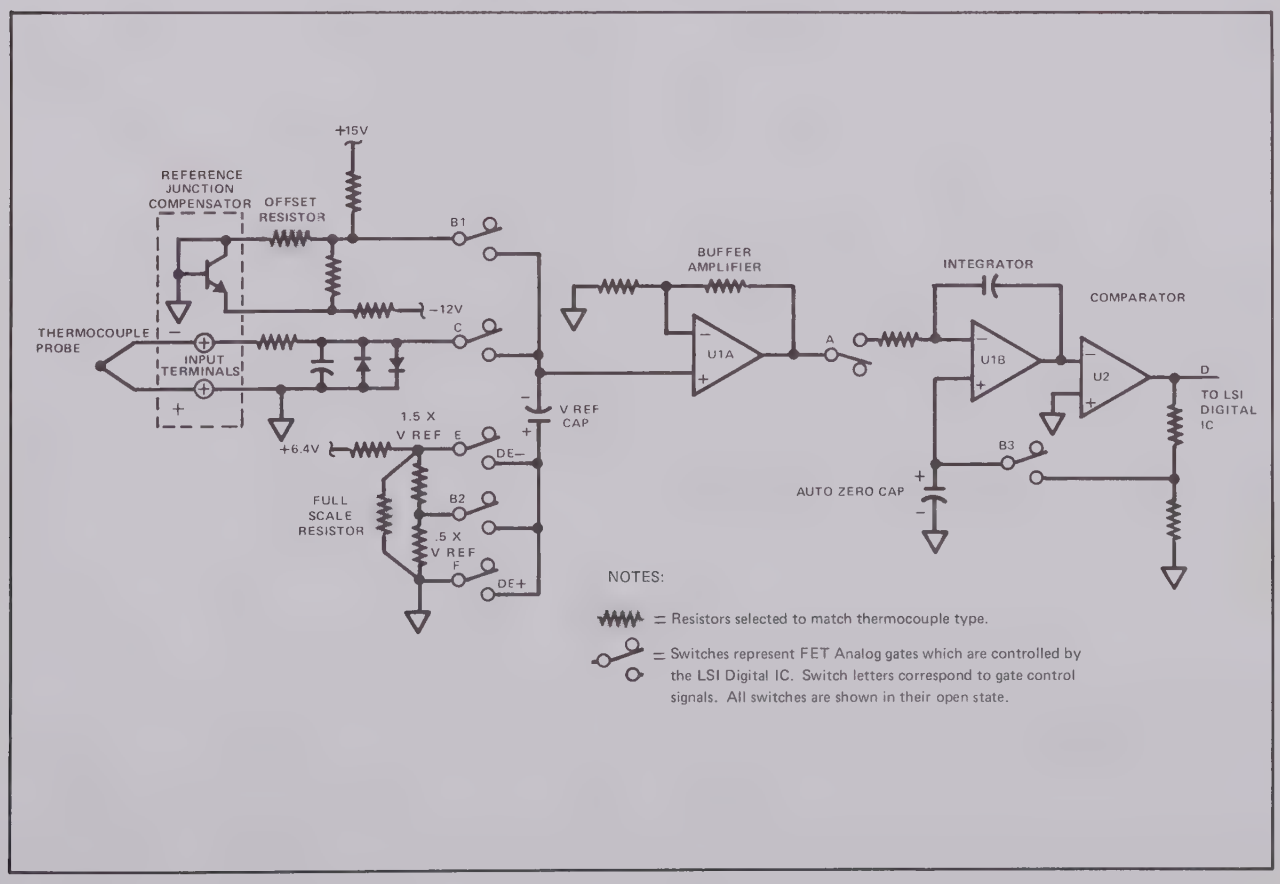


Figure 3-3. ANALOG SECTION, SIMPLIFIED CIRCUIT DIAGRAM

3-21. During the first phase of each measurement cycle, the analog section goes through an Auto-Zero period. During this time, three auto-zero switches (B1, B2 and B3) are closed by the Auto Zero command from the LSI digital IC. Two of the switches (B1 and B2) charge the V ref capacitor to a level equal to the algebraic sum of the 0.5 x V ref output, plus the correction voltage generated by the Reference-Junction Compensator. At the same time, the correction voltage is amplified by the Buffer Amplifier and presented through switch A to the Integrator input. The third switch (B3) connects the Integrator and Comparator in a closed loop configuration and allows the Auto-Zero capacitor to charge to a value which is proportional to the Reference-Junction-Compensator correction voltage plus the offset voltages present in the Buffer, Integrator and Comparator amplifiers. At the end of the measurement cycle switches B1, B2 and B3 are opened. The V ref capacitor and the Auto-Zero capacitor retain their charge for use later in the measurement cycle.

3-22. The Integrate period starts on the leading edge of the Integrate Command from the LSI digital IC; switch A is open and switch C is closed. The thermocouple input voltage is applied through switch C to the Buffer input. After a 500 us settling period, switch A closes and the Buffer output voltage is applied to the Integrator input for 100 ms. As the integrator capacitor charges, the Integrator drives the Comparator output to either 0 or +5V dc to indicate the polarity of the thermocouple input voltage, positive or negative, respectively. The comparator output is sent to the LSI digital IC for use during the Read period. At the end of the Integrate period, the integrator capacitor is charged to a level and polarity that is proportional to the thermocouple probe voltage and switch C returns to its open state.

3-23. The Read period starts at the end of the Integrate period and one-of-two Read Modes is enabled depending upon the input polarity sensed by the comparator during the Integrate period. If a positive input is sensed, a DE– Read Mode is enabled. Similarly a DE+ Read Mode is enabled when a negative input is sensed.

3-24. If the DE– Read Mode is commanded, switch A is opened and E is closed. Switch E applies a 1.5 x V ref input to the positive side of the V ref capacitor. This voltage is algebraicly added to the voltage stored in the V ref capacitor during the previous Auto-Zero period (0.5 x V ref + Reference-Junction-Compensator voltage). As a result, the input to the Buffer Amplifier is a positive voltage equal to V ref plus the Reference Junction-Compensator voltage.

3-25. If the DE+ Read Mode is commanded, switch A is opened and F is closed. Switch F grounds the positive side of the V ref capacitor and causes the Buffer amplifier input to be driven to the voltage stored in the V ref capacitor during the previous Auto-Zero period (0.5 x V ref + Reference-Junction Compensator voltage). As a result, the input to the Buffer Amplifier is a negative voltage equal to 0.5 x V ref plus the Reference-Junction-Compensator voltage.

3-26. After a 500 us settling time, switch A closes and the Buffer output voltage is applied to the Integrator input. This causes the integrator capacitor to discharge at a linear rate determined by the reference voltage. The discharge continuses until the integrator output voltage reaches zero volts, the level existing prior to the integrate period. This level is sensed by the Comparator which signals the LSI digital IC to terminate the A/D conversion of measurement data.

3-27. Offset voltages present during the Integrate and Read periods are cancelled out by offset voltages that were sampled and held during the Auto-Zero period. However, the Reference-Junction-Compensator voltage (also sampled and held during Auto Zero) is added to the integrator voltage during the Integrate period. As a result, the displayed temperature is equal to the thermocouple probe temperature.

3-28. POWER SUPPLY

3-29. The 2160A power supply consists of a power transformer, fuse, power input cord, and regulating circuitry. The function of the power supply is to provide +5, +7.5, +15 and −12V dc operating voltages for the 2160A circuitry. In addition a +5V ac output is available for use by ground-isolated output options. The +7.5, +15 and −12V dc supplies are regulated, and the +5V dc supply is unregulated. All operating voltages are generated using conventional regulating and/or isolating techniques. Refer to the detailed schematic in Section 8 of this manual.

Section 4
Maintenance

WARNING!

THESE SERVICING INSTRUCTIONS ARE FOR USE BY QUALIFIED PERSONNEL ONLY. TO AVOID ELECTRIC SHOCK, DO NOT PERFORM ANY SERVICING OTHER THAN THAT CONTAINED IN THE OPERATING INSTRUCTIONS UNLESS YOU ARE QUALIFIED TO DO SO.

4-1. INTRODUCTION

4-2. This section of the manual contains maintenance information for the Model 2160A Digital Thermometer. This includes service information, general maintenance, a performance test and calibration. The performance test is recommended as an acceptance test when the instrument is first received, and later as a preventive maintenance tool to verify specifications after repair. A calibration cycle of one year is recommended to maintain the unit within the one-year specifications. If the 90-day specifications are to be maintained a 90-day calibration cycle is recommended. Table 4-1 lists the equipment required for both the performance test and calibration. If the recommended model is not available, a substitute that meets the minimum use specifications may be used.

Table 4-1. TEST EQUIPMENT REQUIREMENTS

INSTRUMENT TYPE	MINIMUM USE SPECIFICATIONS	RECOMMENDED MODEL
Thermocouple Probes	Type J, K, T, E, R, S, B or C (select type compatible with thermometer)	Omega TJ36 Series, Grounded Sheath
Mercury Thermometer	0.02°C Resolution	Printco Model ASTM-56C
Dewar Flask and Cap	1-pint capacity	Thermos Bottle
DC Voltage Calibrator	Output Voltage: 0 to 100V Accuracy: 0.002% Resolution: 10 uV	Fluke Model 343A
Variable Line-Voltage Transformer	100, 115 or 230 V ac ±10%, as required	Variac
Resistors	100Ω ±.005% 1/8W, TC ±1ppm 9900Ω ±.005% 1/8W, TC ±1ppm	Dale Type WWA

4-3. SERVICE INFORMATION

4-4. The 2160A is warranted for a period of one year upon delivery to the original purchaser. The WARRANTY is located on the back of the title page located in the front of this manual.

4-5. Factory Authorized calibration and service for each Fluke product is available at various world-wide locations. A complete list of these service centers is included in Section 7 of this manual. If requested, an estimate will be provided to the customer before any work is begun on instruments that are beyond the warranty period.

4-6. GENERAL MAINTENANCE

4-7. Routine Calibration Access

4-8. The adjustments necessary to perform routine calibration on the 2160A are located behind the red-plastic display lens on the front panel. The adjustments are accessed by lifting the bottom-center of the lens with a small screw driver until it pops out of position. The lens is replaced by placing one side into position and then bowing the lens away from the front panel until the other side can be pushed into position. When the lens is released, it secures itself into place.

4-9. Maintenance Access

4-10. Access to the display and main pcb assemblies is achieved by removing the rear-panel retaining screws located on both sides of the rear panel, and pulling the main pcb assembly out the rear of the case. The unit should be disconnected from line power when the pcbs are being removed or installed.

4-11. Cleaning

4-12. Clean the 2160A periodically to remove dust, grease and other contamination. Use the following procedure:

CAUTION!

Do not use aromatic hydrocarbons or chlorinated solvents to clean the 2160A. They will react with the plastic materials used in the instrument.

a. Clean the front panel and case with a soft cloth dampened with a mild solution of detergent and water.

b. Clean the surface of the pcb using clean dry air at low pressure ($\leq$ 20 psi). If grease is encountered, spray with Freon T.F. Degreaser and remove grime with clean dry air at low pressure.

4-13. Fuse Replacement

WARNING!

DISCONNECT THE UNIT FROM LINE POWER BEFORE ATTEMPTING FUSE REPLACEMENT.

4-14. The input power fuse is located on the interior of the unit near the power transformer. If replacement is necessary, use an AGC 1/16 A fuse.

4-15. Service Tools

4-16. No special tools are required to maintain or repair the 2160A.

4-17. PERFORMANCE TEST

4-18. The performance test, as outlined in Table 4-2, is used to compare the 2160A performance with the list of specifications given in Table 1-3. These tests are suitable for incomming inspection, periodic maintenance and to verify specifications. A Performance Test Checklist is provided at the end of this section. If the instrument fails to meet any of its specifications, repair or calibration is required.

NOTE

The performance test should be conducted at an ambient temperature of 25 $\pm 2^{\circ}$C.

Table 4-2. PERFORMANCE TEST DESCRIPTION

TEST INSTRUMENT PARAMETERS	PERFORMANCE SPECIFICATIONS	TEST METHOD
Line Voltage Regulation	Satisfactory Performance with any line voltage within $\pm$10% of nominal; 100, 115 or 230V ac	The display is monitored during the accuracy test as the line voltage is varied.
Accuracy Test	Temperature Accuracy as stated in Table 2 of 1-3. (Table 1 specifications are ensured when Table 2 specifications are verified.)	Known input voltages are substituted for the thermocouple inputs. Cardinal-point checks ensure accuracy over the entire temperature range.
Overload and Open Input Test	The display flashes to indicate both over range input voltages and open input terminals.	An over range voltage is applied to the thermocouple input terminals, and the input terminals are open circuited.
Internal Temperature Rise	$<5^{\circ}$C above ambient	The thermocouple input terminals are shorted and the temperature of the reference junction is displayed.

4-19. Initial Procedure

4-20. Complete the following procedure prior to executing the performance test:

a. Connect a variable line-power transformer to line power and adjust the output to the nominal line voltage at which the 2160A is designed to operate; 100, 115 or 230V ac.

b. Connect the 2160A power cord to the transformer output.

c. Prepare a 32°F ice-point bath using a thermos bottle and a mercury thermometer.

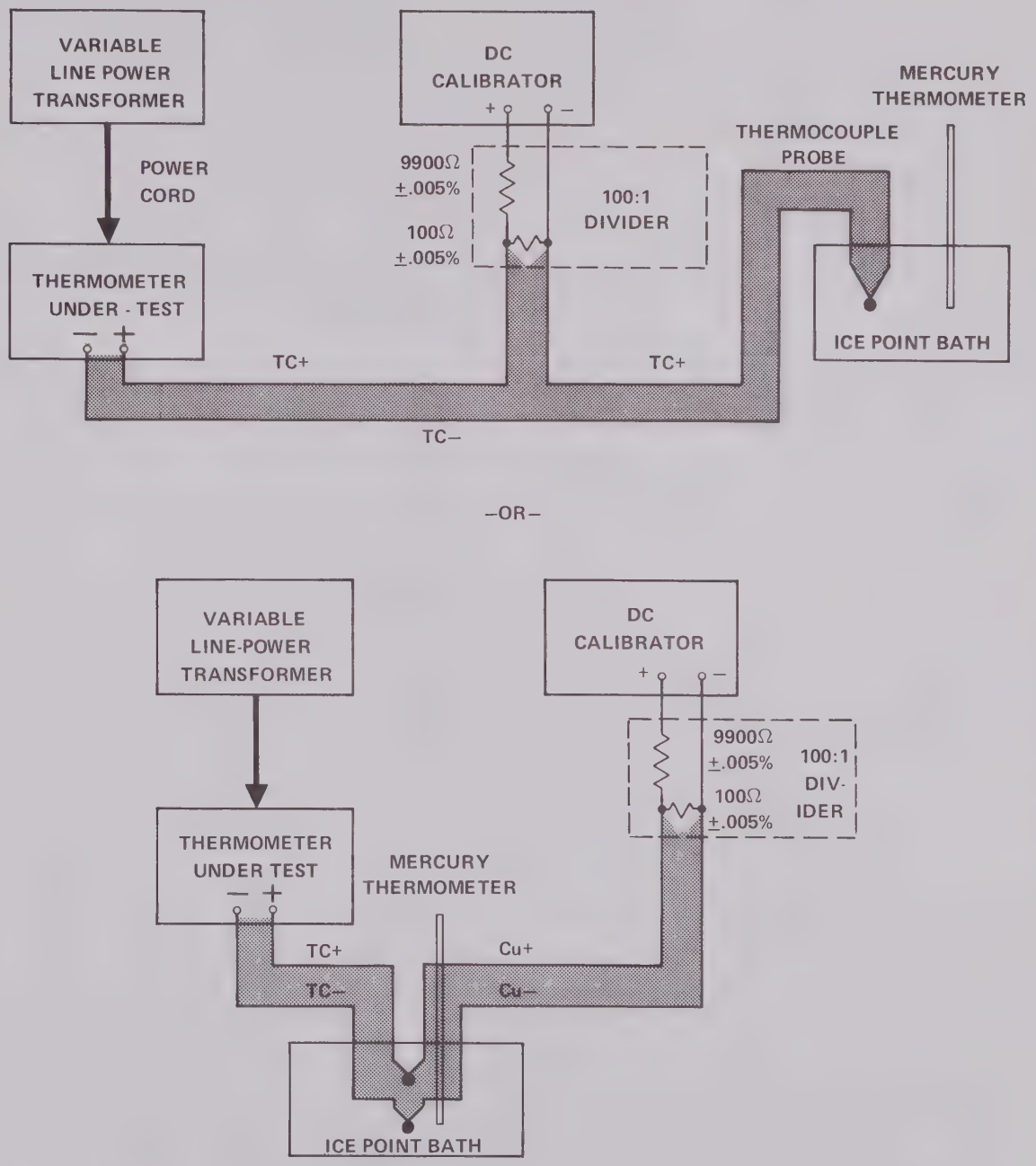
d. Complete the equipment connections shown in Figure 4-1.

NOTE

The thermocouple probe type must be compatible with the 2160A under test.

e. Set the calibrator for a 0V dc output and select the 10 V range.

f. Energize the calibrator.



NOTES:

1. ▒ = Thermocouple wire
2. If the thermometer is designed to operate with a type B thermocouple, the thermocouple probe(s) and ice bath can be deleted from the test set-up. Connect the divider output directly to the thermometer inputs using copper wire.

Figure 4-1. PERFORMANCE–TEST EQUIPMENT CONNECTIONS

4-21. Line Voltage Regulation

4-22. Line voltage regulation is tested in conjunction with the accuracy test given in the following paragraph. As the accuracy test is executed, vary the line voltage ±10% with a variable line-power transformer to ensure proper operation within the line-voltage limits.

4-23. Accuracy Test

4-24. Use the following procedure to test the 90-day or 1-year accuracy of the 2160A:

NOTE

Optimum accuracy is ensured by checking the unit on the °F temperature scale. However, for convenience, both the °F and °C accuracy measurements are given in Table 4-3.

a. Refer to Table 4-3 and select the group of figures that correspond to the thermocouple type used with the 2160A.

b. Sequentially, set the calibrator to obtain each of the divider output voltages listed within the selected group, and check the thermometer display against the appropriate display limits; 90-day or 1-year.

4-25. Overload and Open Input

4-26. Use the following procedure to test the 2160A's overload and open-circuit detectors:

a. Set the calibrator output to 10 V dc. The thermometer display should begin to flash. While the display is lit, it should read the high end of the temperature range assigned to the compatible thermocouple type:

J	=	1432°F	or	778°C
K	=	2472°F	or	1356°C
T	=	752°F	or	400°C
E	=	1832°F	or	1000°C
R	=	3232°F	or	1778°C
S	=	3232°F	or	1778°C
B	=	3352°F	or	1844°C
C	=	3999°F	or	2328°C

Table 4-3. TEMPERATURE ACCURACY

TYPE	DIVIDER OUTPUT (mV dc)	°F DISPLAY LIMITS 90 DAY	°F DISPLAY LIMITS 1 YEAR	DIVIDER OUTPUT (mV dc)	°C DISPLAY LIMITS 90 DAY	°C DISPLAY LIMITS 1 YEAR
J	42.640	1390.5 to 1393.5	1390 to 1394	42.640	754.6 to 756.6	754.1 to 757.1
	2.288	110.5 to 113.5	110 to 114	2.288	43.4 to 45.4	42.9 to 45.9
	–1.643	–30 to –26	–30.5 to –25.5	–2.175	–45.9 to –42.9	–45.9 to –42.9
	–7.634	–310 to –306	–310.5 to –305.5	–7.344	–179.3 to –176.3	–179.3 to –176.3
K	52.789	2389.5 to 2394.5	2389 to 2395	49.638	1220.7 to 1223.7	1220.2 to 1224.2
	2.709	149.5 to 154.5	149 to 155	6.623	154.1 to 157.1	153.6 to 157.6
	–1.691	–50.5 to –45.5	–51 to –45	–1.691	–45.9 to –42.9	–46.4 to –42.4
	–5.713	–310.5 to –305.5	–311 to –305	–5.510	–179.3 to –176.3	–179.8 to –175.8
T	20.188	730.5 to 733.5	730 to 734	20.188	376.8 to 378.8	376.8 to 378.8
	0.879	70.5 to 73.5	70 to 74	0.8789	21.2 to 23.2	21.2 to 23.2
	–1.240	–30 to –26	–31.5 to –24.5	–2.009	–57.1 to –54.1	–57.6 to –53.6
	–5.421	–310 to –306	–311.5 to –304.5	–5.221	–179.3 to –176.3	–179.8 to –175.8
E	74.694	1790 to 1794	1789.5 to 1794.5	74.694	976.8 to 978.8	976.3 to 979.3
	2.694	110 to 114	109.5 to 114.5	2.694	43.4 to 45.4	42.9 to 45.9
	–1.897	–30 to –26	–31.5 to –24.5	–3.080	–57.1 to –54.1	–57.6 to –53.6
	–8.529	–310 to –306	–311.5 to –304.5	–8.209	–179.3 to –176.3	–179.8 to –175.8
R	20.951	3188 to 3196	3187 to 3197	20.951	1753.1 to 1757.1	1752.6 to 1758.6
	0.259	108 to 116	107 to 117	0.259	41.9 to 46.9	41.4 to 47.4
S	18.321	3148.5 to 3155.5	3147.5 to 3156.5	17.295	1642.4 to 1646.4	1641.4 to 1647.4
	0.262	109.5 to 111.5	107.5 to 116.5	0.262	42.2 to 46.4	41.4 to 47.4
B	13.585	3268.5 to 3276.5	3267.5 to 3276.5	13.585	1798 to 1802	1797.5 to 1802.5
	1.535	1028.5 to 1035.5	1027.5 to 1036.5	1.661	575.8 to 579.8	575.3 to 580.3
C	38.227	3976 to 3988	3975.5 to 3988.5	38.227	2190.9 to 2197.9	2190.4 to 2198.4
	1.005	186 to 198	185.5 to 198.5	0.457	40.9 to 47.9	40.4 to 48.4

b. Set the calibrator output to 0V dc.

c. Remove the input connections at the thermometers thermocouple input terminals. The display should begin to flash and read the high end of the temperature range as described in step a of this procedure.

4-27. Internal Temperature Rise

4-28. Use the following procedure to measure the thermometer's internal temperature as sensed by the reference junction:

NOTE

This procedure assumes that the thermometer has been energized for at least 30 minutes and allowed to stabilize at an ambient temperature of 25 ±2°C.

a. Monitor the ambient temperature (room temperature) using a mercury thermometer.

b. Connect a copper wire between the 2160A's thermocouple input terminals. The unit will display the temperature of the internal reference junction. This temperature should not exceed the ambient temperature by more than 5°C.

c. Remove the short from the thermocouple input terminals and disconnect the unit from the power transformer.

4-29. CALIBRATION

4-30. The 2160A should be calibrated once a year or every 90 days, as required to maintain the desired accuracy. Calibration should also be performed after the unit has been repaired and after the thermocouple type select pcb has been changed.

4-31. Routine calibration (periodic calibration or when a type select pcb is changed) may be accomplished using either one-of-two calibration methods. The recommended method (and the most accurate) is a voltage calibration technique utilizing a single temperature point. The second method is the traditional ice-point-reference technique as outlined earlier in this section under Performance Test.

4-32. If the ice-point-reference method is used, complete the set-up procedure for the performance test, as given earlier in this section. Then adjust the Offset Pot (see Figure 4-2) to obtain a display equal to the ice-point reference, 0°C or 32°F. Finally, set the calibrator output to obtain the appropriate divider output voltage, as given in Table 4-4, and adjust the Full Scale Cal pot to obtain the corresponding display reading.

4-33. The voltage calibration method, as given in the following procedure, is recommended for both routine calibra-

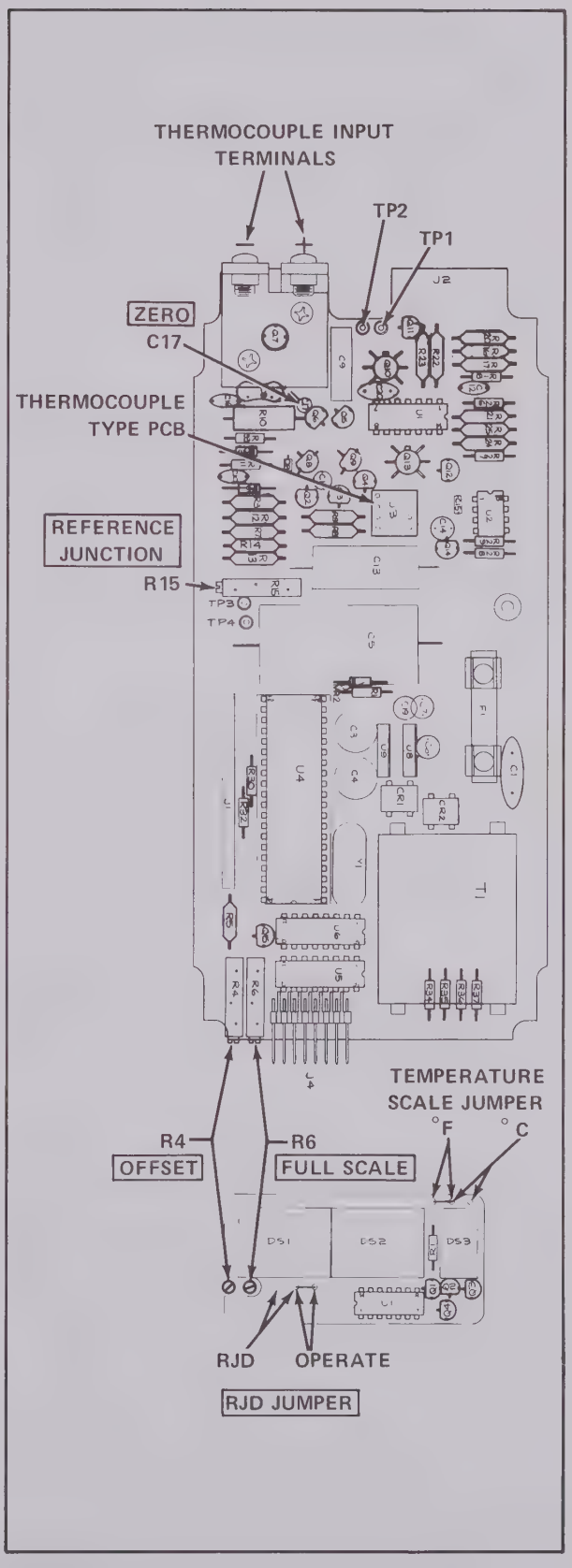


Figure 4-2. TEST POINT AND ADJUSTMENT LOCATIONS

Table 4-4. FULL SCALE CALIBRATION

PROBE TYPE	°F		°C	
	DIVIDER OUTPUT (mV dc)	DISPLAY READING	DIVIDER OUTPUT (mV dc)	DISPLAY READING
J	+42.640	1392°F	+42.640	755.6°C
K	+52.789	2392°F	+49.638	1222.2°C
T	+20.188	732°F	+19.497	377.8°C
E	+74.694	1792°F	+74.694	977.8°C
R	+20.951	3192°F	+20.951	1755.6°C
S	+18.321	3152°F	+17.295	1644.4°C
B	+13.585	3272°F	+13.585	1800.0°C
C	+38.227	3982°F	+38.227	2194.4°C

tion and calibration after repair. The procedure allows the unit to be calibrated on either the °C or °F scale (Calibrating either scale ensures the accuracy of both scales). Interpolation of the least significant digit is necessary when calibrating the unit. However, calibrating on the °F scale requires interpolation of ±½ a digit, where as, calibrating on the °C scale requires interpolation of ±¼ of a digit. The accuracy of either or both scales can be verified after calibration by executing the performance test given earlier in this section.

NOTE

For routine calibration, skip the shaded steps in the following procedure. For calibration after repair, perform both the shaded and unshaded steps.

a. Remove the red-plastic display lens for routine calibration or, if calibration after repair is being performed, remove the pcb assemblies from the case.

b. Locate the temperature-scale jumper (°F/ °C) on the Display PCB (See Figure 4-2) and select the desired temperature scale (°C or °F). Either scale may be used for calibration.

NOTE

For B type thermocouples skip step C. The RJD jumper should remain in the operate position.

c. Locate the reference junction defeat (RJD) jumper on the Display PCB and install it in the RJD position.

d. Complete the equipment connections shown in Figure 4-3.

1. Set dc voltage calibrator to: 10V range, 0V output.

2. Construct 100:1 divider using resistors specified in Table 4-1.

e. Connect the voltage divider output to the 2160A thermocouple input terminals (match polarities).

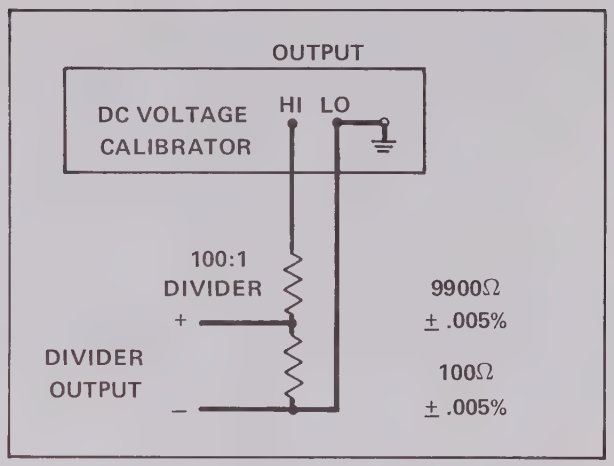


Figure 4-3. EQUIPMENT CONNECTIONS

f. Connect the thermometer to the appropriate line voltage and energize the unit.

g. Adjust C17 as necessary to obtain a flashing minus sign (–) on the thermometer display.

h. Determine the thermocouple type that is compatible with the thermometer by locating the plug-in Thermocouple Type PCB as shown in Figure 4-2. The thermocouple type is marked on the pcb.

i. Refer to Table 4-4 and set the calibrator output to obtain the voltage divider output specified for the compatible thermocouple type.

j. Adjust the Full Scale pot (R6) to obtain the temperature display specified in Table 4-4.

k. Return the RJD jumper to the operate position.

l. Remove the voltage divider leads from the thermocouple input terminals.

NOTE

This completes the calibration procedure for units compatible with B type thermocouples.

m. Short the thermocouple input terminals using a small piece of hook-up wire.

n. Select the 100V range on the calibrator and set the calibrator output to 57.8500V dc.

CAUTION!

Make sure the voltage divider output is 578.5mV before going to the next step.

o. Connect the voltage divider output to TP1 (+) and TP2 (–) as shown in Figure 4-2.

p. Adjust the Offset pot (R4) for a temperature display of 77°F or 25°C.

q. Remove the short at the thermocouple input terminals.

r. Connect the compatible type of thermocouple probe to the thermocouple inputs (observe polarity).

s. Place the thermocouple probe in a lag bath of known temperature. Use an accurate mercury thermometer to monitor the temperature of the bath.

t. Adjust the Reference Junction Pot (R15) to obtain a display reading that agrees with the lag-bath temperature. Use LSD flicker for interpolation.

NOTE

If the shaded steps of this procedure have been performed, skip step u.

u. Adjust the Offset Pot (R4) to obtain a display reading that agrees with the lag-bath temperature.

v. Recheck and, if necessary, reset the full scale adjustment by repeating steps d, e, h, i, j, and k of this procedure.

w. Disconnect the thermocouple from the input terminals and re-assemble the 2160A.

4-34. TROUBLESHOOTING

4-35. A troubleshooting guide for the 2160A is given in Table 4-5. The guide is in the form of a tabular flow chart and is recommended for use in isolating a problem to a functional circuit group. Details necessary to troubleshoot a fault in a functional circuit group can be derived from Section 3, Theory of Operation, and Section 8, Schematic Diagrams.

Table 4-5. TROUBLESHOOTING GUIDE

STEP	INSTRUCTION	YES	NO	GO TO
1	Energize the unit and connect a short across the thermocouple input terminals.			2
2	Does the display light?	16	3	
3	Is the power fuse blown?	4	5	
4	Replace fuse.			2
5	Are all power supply voltages present; +5, +7.5, +15 and −12V dc?	7	6	
6	Repair power supply.			2
7	Are Strobe Out pulses present at pins 9, 10, 11 and 12 of U4. (Use logic common as reference.)?	10	8	
8	Is crystal operating?	10	9	
9	Replace crystal.			2
10	Are display drivers functioning?	13	11	
11	Is output data present at pins 4, 5, 6 and 7 of U4?	12	13	
12	Replace display drivers as necessary.			2
13	Are $\overline{\wedge}$2, A2, INT, DE+ or DE−, and CM present at U4?	14	15	
14	Display PCB defective. Repair as necessary.			2
15	U4 is defective. Replace.			2
16	Does display read approximate ambient temperature?	21	17	
17	Refer to Section 3 of this manual and use a scope to check for the presence of the waveforms shown in Figure 3-2.			18
18	Are all waveforms correct?	20	19	
19	Perform the necessary repairs to the analog circuit.			17
20	Calibrate the thermometer.			21
21	End. Thermometer is functional.			

PERFORMANCE TEST CHECKLIST

Fluke Model 2170A Digital Thermometer

Serial No. _____

Tested By _____

Date _____

Line Voltage Regulation . . . . . Passed ( ) Failed ( )

Accuracy Test . . . . . See Verification Tables

°F VERIFICATION TABLE

PROBE TYPE	NOMINAL TEMPERATURE °F	90 DAY			1 YEAR		
		MIN.	ACTUAL	MAX.	MIN.	ACTUAL	MAX.
J	1392	1390.5		1393.5	1390		1394
	112	110.5		113.5	110		114
	–28	–30		–26	–30.5		–25.5
	–308	–310		–306	–310.5		–305.5
K	2392	2389.5		2394.5	2389		2395
	152	149.5		154.4	149		155
	–48	–50.5		–45.5	–51		–45
	–308	–310.5		–305.5	–311		–305
T	732	730.5		733.5	730		734
	72	70.5		73.5	70		74
	–28	–30		–26	–31.5		–24.5
	–308	–310		–306	–311.5		–304.5
E	1792	1790		1794	1789.5		1794.5
	112	110		114	109.5		114.5
	–28	–30		–26	–31.5		–24.5
	–308	–310		–306	–311.5		–304.5
R	3192	3188		3196	3187		3197
	112	108		116	107		117
S	3152	3148.5		3155.5	3147.5		3156.5
	112	109.5		113.5	107.5		116.5
B	3272	3268.5		3275.5	3267.5		3276.5
	1032	1028.5		1035.5	1027.5		1036.5
C	3982	3976		3988	3975.5		3988.5
	192	186		198	185.5		198.5

PERFORMANCE TEST CHECKLIST, Cont.

Overload

Overrange . . . . . Passed ( ) Failed ( )

Open Circuit . . . . . Passed ( ) Failed ( )

Internal Temperature Rise . . . . . < 5°C above ambient

°C VERIFICATION TABLE

PROBE TYPE	NOMINAL TEMPERATURE °C	90 DAY			1 YEAR		
		MIN.	ACTUAL	MAX.	MIN.	ACTUAL	MAX.
J	755.4	754.6		756.6	754.1		757.1
	44.4	43.4		45.4	42.9		45.9
	–45.9	–45.9		–42.2	–45.9		–42.9
	–178.8	–179.3		–176.3	–179.3		–176.3
K	1222.2	1220.7		1223.7	1220.2		1224.2
	155.6	154.1		157.1	153.6		157.6
	–44.4	–45.9		–42.9	–46.4		–42.4
	–177.8	–179.3		–176.3	–179.8		–175.8
T	377.8	376.8		378.8	376.8		378.8
	22.2	21.2		23.2	21.2		23.2
	–55.6	–57.1		–54.1	–57.6		–53.6
	–177.8	–179.3		–176.3	–179.8		–175.8
E	977.8	976.8		978.8	976.3		979.3
	44.4	43.4		45.4	42.9		45.9
	–55.6	–57.1		–54.1	–57.6		–53.6
	–177.8	–179.3		–176.3	–179.8		–175.8
R	1755.6	1753.1		1757.1	1752.6		1758.6
	44.4	41.9		46.9	41.4		47.4
S	1644.4	1642.4		1646.4	1641.4		1647.4
	44.4	42.2		46.4	41.4		47.4
B	1800	1798		1802	1797.5		1802.5
	577.8	575.8		579.8	575.3		580.3
C	2194.4	2190.9		2197.9	2190.4		2198.4
	44.4	40.8		47.9	40.4		48.4

Section 5

Lists of Replaceable Parts

REFERENCE DESIGNATOR	ASSEMBLY NAME/NUMBER	PART NO.	PAGE
	Digital Thermometer, Final Assembly (2160A)	———	5-3
A1	Thermometer Assembly		
	100V ac (2160A-4010T-2)	420737	5-4
	115V ac (2160A-4010T)	420703	5-4
	230V ac (2160A-4010T-3)	420752	5-4
A1A1	Thermometer PCB Assembly (2160A-4010)	415604	5-5
A1A2	Display PCB Assembly (2160A-4020)	415943	5-8
A2	Type Select PCB Assembly	———	5-9

5-1. INTRODUCTION

5-2. This section contains an illustrated parts breakdown of the instrument. Components are listed alpha-numerically by assembly. Electrical components are listed by reference designation and mechanical components are listed by item number. Each listed part is shown in an accompanying illustration.

5-3. Parts lists include the following information:

a. Reference Designation or Item Number.

b. Description of each part.

c. Fluke Stock Number.

d. Federal Supply Code for Manufacturers. (See Appendix A for Code-to-Name list.)

e. Manufacturer's part Number or Type.

f. Total Quantity per assembly or component.

g. Recommended Quantity: This entry indicates the recommended number of spare parts necessary to support one to five instruments for a period of two years. This list presumes an availability of common electronic parts at the maintenance site. For maintenance for one year or more at an isolated site, it is recommended that at least one of each assembly in the instrument be stocked. In the case of optional subassemblies, plug-ins, etc. that are not always part of the instrument, or are deviations from the basic instrument mode, the REC QTY column lists the recommended quantity of the item in that particular assembly.

h. Use Code is provided to identify certain parts that have been added, deleted or modified during production of the instrument. Each part for which a use code has been assigned may be identified with a particular instrument serial number by consulting the Use Code Effectivity, paragraph 5-7.

5-4. HOW TO OBTAIN PARTS

5-5. Components may be ordered directly from the manufacturer by using the manufacturer's part number, or from the John Fluke Mfg. Co., Inc. factory or authorized representative by using the FLUKE STOCK NUMBER. In the event the part you order has been replaced by a new or improved part, the replacement will be accompanied by an explanatory note and installation instructions, if necessary.

5-6. To ensure prompt and efficient handling of your order, include the following information.

a. Quantity

b. FLUKE Stock Number

c. Description

d. Reference Designation or Item Number

e. Printed Circuit Board Part Number

f. Instrument model and Serial number

5-7. USE CODE EFFECTIVITY LIST

USE CODE	SERIAL NUMBER EFFECTIVITY

FINAL ASSEMBLY, 2160A

REF DESIG OR ITEM NO.	DESCRIPTION	FLUKE STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
	DIGITAL THERMOMETER FINAL ASSEMBLY 2160A						
A1	Thermometer Assembly				1		
	110V ac (2160A-4010T-2)	420737	89536	420737			
	115V ac (2160A-4010T)	420703	89536	420703			
	230V ac (2160A-4010T-3)	420752	89536	420752			
A2	Type Select PCB Assembly				1		
	One-of-eight possible type select pcb assemblies is supplied with the unit.						
	R Type Select PCB Assembly (2160A-4012)	415612	89536	415612			
	S Type Select PCB Assembly (2160A-4013)	415620	89536	415620			
	B Type Select PCB Assembly (2160A-4014)	415638	89536	415638			
	C Type Select PCB Assembly (2160A-4015)	415646	89536	415646			
	J Type Select PCB Assembly (2160A-4016)	415653	89536	415653			
	K Type Select PCB Assembly (2160A-4017)	415661	89536	415661			
	T Type Select PCB Assembly (2160A-4018)	415927	89536	415927			
	E Type Select PCB Assembly (2150A-4019)	415935	89536	415935			
1	Bezel, panel meter	394502	89536	394502	1		
2	Case, extrusion	415505	89536	415505	1		
3	Decal, front-panel	416768	89536	416768	1		
4	Decal, model	416784	89536	415784	1		
5	Decal, serial-number	416776	89536	416776	1		
6	Decal, thermocouple-type	416792	89536	416792	1		
7	Insulator	415513	89536	415513	1		
8	Lens, plastic	413716	89536	413716	1		
9	Pawl, cast	407437	89536	4107437	1		

A1 THERMOMETER ASSEMBLY

REF DESIG OR ITEM NO.	DESCRIPTION	FLUKE STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
A1	THERMOMETER ASSEMBLY				REF		
	110V ac (2160A-4010T-2)	420737	89536	420737			
	115V ac (2160A-4010T)	420703	89536	420703			
	230V ac (2160A-4010T-3)	420752	89536	420752			
A1A1	Thermometer PCB Assembly (2160A-4010)	415604	89536	415604	1		
A1A2	Display PCB Assembly (2160A-4020)	415943	89536	415943	1		
T1	Transformer, power				1		
	100V ac (2160A-6512)	421032	89536	421032			
	115V ac (2160A-6510	421057	89536	421057			
	230V ac (2160A-6511)	421040	89536	421040			
U4	LSI Digital IC	393777	89536	393777	1		
	Cord and plug, ac line	102822	70903	PH-70	1	1	
	Panel. rear	413799	89536	413799	1		

A1A1 THERMOMETER PCB ASSEMBLY

REF DESIG OR ITEM NO.	DESCRIPTION	FLUKE STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
A1A1	**THERMOMETER PCB ASSEMBLY (2160A-4010)** **Figure 8-1**	415604	89536	415604	REF		
C1	Cap, cer, .01 uF ±20%, 3kV	266320	56289	41C301A2	1		
C3, C4	Cap, elect, 100 uF −10/+100 25 V	416982	56289	503D107 CG	1	1	
C5	Cap, elect, 4000 uF +100/−10%, 10V	330761	25088	B41010-4700/10	1	1	
C6, C7, C14,C19	Cap, Ta, 10 uF ±20%, 20V	330662	56289	196D106X0020 JA1	4		
C8	Cap, mica, 100 pF ±1%, 500V	226126	71234	DM15F100F	1		
C9	Cap, mylar, 0.47 uF ±10%, 100V	369124	73445	C280MA/H470K	1		
C10	Cap, disc, 100 pF ±10%, 1kV	105593	71590	DD101	1		
C11	Cap, Ta, 2.2 uF ±10%, 15V	364216	56289	196D222X9015 H1A	1		
C12	Cap, cer, .025 uF ±20%, 100V	168435	56289	C023B101H253 M	1		
C13	Cap, polypro, 0.47 uF ±10%, 50V	363085	01281	JF86	1		
C15	Cap, cer, 2700 pF ±20%, 100V	362889	72982	8121-A100-W5R 272M	1		
C16,C20	Cap, cer, 1000 pF ±10%, 500V	357806	56289	C106B102G102K	2		
C17	Cap, var, 0.25 - 1.5 pF, 2kV	218206	72982	530-000	1	1	
C18	Cap, cer, 1 pF ±0.25 pF, 100V	436477	72982	8101-A100-C0G-1 09G	1		
CR1, CR2,	Diode, bridge rectifier	418582	50044	VM08	2	1	
CR3	Diode, Si, 150mA, 75V	203323	09214	1N4148	1	1	
F1	Fuse, fast blo, 1/16A	109348	71400	AGC1-16	1	5	
J1	Connector, female, 18-pin	435024	00779	583773-8	1		
Q2 thru Q6,Q8, Q9,Q12, Q14	Xstr, J-FET, N-channel	343830	32293	ITS30168	9	2	
Q7	Xstr, Si, NPN	329698	07263	2N2484	1	1	

A1A1 THERMOMETER PCB ASSEMBLY (Cont.)

REF DESIG OR ITEM NO.	DESCRIPTION	FLUKE STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
Q10	Xstr, FET, dual N-channel	439703	89536	439703	1	1	
Q11, Q15,	Xstr, Si, NPN	218396	04713	2N3904	2	1	
Q13	Xstr, FET, dual N-channel	379321	17856	E7024	1	1	
R1	Res, comp, 430 ±5%, ¼W	203869	01121	CB4315	1		
R3	Res, mf, 15.8k ±1%, 1/8W	293688	91637	MFF1-81582F	1		
R4	Res, var, 25k ±20%, ½W	285213	71450	190PC253B	1	1	
R5	Res, mf, 261k ±1%, 1/8W	257535	91637	MFF1-82613F	1		
R6	Res, var, 10k ±20%, ½W	267880	71450	190PC103B	1	1	
R7	Res, mf, 195k ±0.1%, 1/8W	436485	91637	MFF1-81953BS	1		
R8	Res, mf, 2k ±0.1%, 1/8W	340174	91637	MFF1-82001BS	1		
R9	Res, mf, 1k ±0.1%, 1/8W	340380	91637	MFF1-81001BS	1		
R10	Res, comp, 47k ±5%, 1W	150219	01121	GB4735	1		
R11, R29	Res, comp, 1M ±5%, ¼W	182204	01121	CB1055	2		
R12	Res, mf, 26.7k ± .1%, 1/8W	344465	91637	MFF1-82672BS	1		
R13	Res, mf, 150k ±1%, 1/8W	241083	91637	MFF1-81503F	1		
R15	Res, var, 50k ±20%, ½W	330688	71450	190PC504B	1	1	
R16, R17	Res, mf, 14.7k ±1%, 1/8W	226225	91637	MFF1-81472F	2		
R18	Res, comp, 470 ±5%, ¼W	147983	01121	CB4715	1		
R20	Res, mf, 28.7k ±1%, 1/8W	235176	91637	MFF1-82872F	1		
R21	Res, mf, 61.9k ±1%, 1/8W	237230	91637	MFF1-86192F	1		
R22	Res, mf, 19.1k ±1%, 1/8W	234963	91637	MFF1-81912F	1		
R23	Res, mf, 1k ±1%, 1/8W	168229	91637	MFF1-81001F	1		
R24, R25	Res, mf, 82.5k ±1%, 1/8W	246223	91637	MFF1-88252F	2		
R26	Res, comp, 680k ±5%, ¼W	188433	01121	CB6845	1		
R27	Res, comp, 100 ±5%, ¼W	147926	01121	CB1015	1		
R28, R33	Res, comp, 220k ±5%, ¼W	160937	01121	CB2245	2		

A1A1 THERMOMETER PCB ASSEMBLY (Cont.)

REF DESIG OR ITEM NO.	DESCRIPTION	FLUKE STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
R30, R32	Res, comp, 20k ±5%, ¼W	221614	01121	CB2035	2		
R34 thru R37	Res, comp, 27k ±5%, ¼W	148148	01121	CB2735	4		
U1	IC, dual opnl ampl	404087	49956	RC4739DP	1	1	
U2	IC, opnl ampl	352195	49956	RC311DN	1	1	
U5	IC, TTL, bcd-to-7 segment decoder driver	340109	01295	SN7447	1	1	
U6	IC, C-MOS, hex buffer/inverter	381830	01295	MM5650AN	1	1	
U8	IC, linear, voltage regulator, +15V	413187	12040	LM340T-18	1	1	
U9	IC, linear, voltage regulator, −12V	381665	04713	MC7912CP	1	1	
VR1	Diode, zener, 6.4V ±2%	393579	04713	1N4567	1	1	
VR2	Diode, zener, 10V	256446	07910	1N755A	1	1	
Y1	Crystal, 400 kHz	403352	89536	403352	1		
1	Connector, post pin	267633	00779	86144-1	8		
2	Header	417030	00779	87230-8	1		
3	Isothermal Block						
	Insulator	415695	89536	415695	1		
	Plate, terminal, neg	415687	89536	415687	1		
	Plate, terminal, pos	415679	89536	415679	1		
4	Socket, IC, 40-pin	418988	91506	340-AG37D	1		

A1A2 DISPLAY PCB ASSEMBLY

REF DESIG OR ITEM NO.	DESCRIPTION	FLUKE STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
A1A2	**DISPLAY PCB ASSEMBLY (2160A-4020)** **Figure 8-2**	415943	89536	415943	REF		
DS1, DS2	LED, dual 7-segment character display	419051	29083	MAN 6610	2	1	
DS3	LED, 7-segment character display	407874	29083	MAN 4610	1	1	
Q1 thru Q4	Xstr, Si,Darlington NPN	381798	04713	MPS A-13	4	1	
R1	Res, comp, 91 ±5%, ¼W	221887	01121	CB9105	1		
U1	IC, res network, 60Ω	344069	89536	344069	1	1	

A2 TYPE SELECT PCB ASSEMBLY

REF DESIG OR ITEM NO.	DESCRIPTION	FLUKE STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
A2	**TYPE SELECT PCB ASSEMBLY**				REF		
	Figure 8-3						
	R Type (2160A-4012)	415612	89536	415612			
P3	Socket, IC, 8-pin	418608	00779	583640-1	1		
R1	Res, mf, 324 ±1%, 1/8W	423780	91637	MFF1-83240F	1		
R2	Res, mf, 69.5 ±0.1%, 1/8W	423756	91637	MFF1-869R5B	1		
	S Type (2160A-4013)	415620	89536	415620			
P3	Socket, IC, 8-pin	418608	00779	583640-1	1		
R1	Res, mf, 324 ±1%, 1/8W	423780	91637	MFF1-83240F	1		
R2	Res, mf, 70 ±0.1%, 1/8W	423764	91637	MFF1-8A700F	1		
	B Type (2160A-4014)	415638	89536	415638			
P3	Socket, IC, 8-pin	418608	00779	583640-1	1		
R1	Res, mf, 143 ±1%, 1/8W	423699	91637	MFF1-81430F	1		
	C Type (2160A-4015)	415646	89536	415646			
P3	Socket, IC, 8-pin	418608	00779	583640-1	1		
R1	Res, mf, 634 ±1%, 1/8W	423798	91637	MFF1-86340F	1		
R2	Res, mf, 123.5 ±0.1%, 1/8W	424564	91637	MFF1-8123R5B	1		
	J Type (2160A-4016)	415653	89536	415653			
P3	Socket, IC, 8-pin	418608	00779	583640-1	1		
R1	Res, mf, 10.7k ±1%, 1/8W	423681	91637	MFF1-81072F	1		
R2	Res, mf, 619 ±0.1%, 1/8W	423715	91637	MFF1-86190B	1		
	K Type (2160A-4017)	415661	89536	415661			
P3	Socket, IC, 8-pin	418608	00779	583640-1	1		
R1	Res, mf, 3.74k ±1%, 1/8W	260547	91637	MFF1-83741F	1		
R2	Res, mf, 481.4 ±0.1%, 1/8W	423723	91637	MFF1-8481R4B	1		

A2 TYPE SELECT PCB ASSEMBLY (Cont.)

REF DESIG OR ITEM NO.	DESCRIPTION	FLUKE STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
	T Type (2160A-4018)	415927	89536	415927			
P3	Socket, IC, 8-pin	418608	00779	583640-1	1		
R1	Res, mf, 3.74k ±1%, 1/8W	260547	91637	MFF1-83741F	1		
R2	Res, mf, 483.7 ±0.1%, 1/8W	423731	91637	MFF1-8483R7B	1		
	E Type (2160A-4019)	415935	89536	415935			
P3	Socket, IC, 8-pin	418608	00779	583640-1	1		
R1	Res, mf, 53.6k ±1%, 1/8W	291401	91637	MFF1-85362F	1		
R2	Res, mf, 732 ±0.1%, 1/8W	423749	91637	MFF1-87320B	1		

Section 6
Option & Accessory Information

6-1. INTRODUCTION

6-2. This section of the manual contains information concerning the Options and Accessories available for use with the Model 2160 A Digital Thermometer. The first portion of this section provides a brief description of each option and accessory. The depth of detail is intended to give the prospective user an adequate first acquaintance with the features and capabilities of each. Detailed information concerning specifications, operating instructions, maintenance, list of replaceable parts, and schematics is supplied separately with some options and accessories, and is designed to comprise the second portion of this section. Unique page and paragraph numbering is assigned to each of the add-on descriptions to allow separation into easily identifiable subsections. The material is prepunched (T-punched) to permit insertion without disassembling the manual. Table 6-1 lists the available options and accessories and defines the manner in which each is documented.

6-3. THERMOCOUPLE PROBES

6-4. Three types of thermocouple probe assemblies (J, K and T) are available from Fluke for use with the 2160A. See Table 6-1. Each thermocouple is enclosed in a 6-inch x 1/8 inch iconel sheath, and includes a heavy duty transition splice and spring. See Figure 6-1. The thermocouple junction is grounded to the sheath, and 36-inch trimmed leads are included on all units. Refer to the Tables under Specifications in Section 1 of this manual for the temperature ranges recommended for each thermocouple type.

6-5. RACK MOUNTING PANELS

6-6. Three rack-mounting panels are available for mounting the 2160A in a standard 19-inch equipment rack. The panels, listed in Table 6-1, provide the option of mounting either one, two or three units. Panel mounting instructions for the 2160A are given in Section 2 of this manual.

Table 6-1. 2160A OPTIONS, ACCESSORIES AND DOCUMENTATION SOURCES

MODEL OR OPTION NO.	DESCRIPTION	DOCUMENTATION SUPPLIED	
		WITH UNIT	HERE IN
P20J	J-Type TC Probe		●
P20K	K-Type TC Probe		●
P20T	T-Type TC Probe		●
2160A-7031	Rack Mtg. Panel, 1 unit		●
2160A-7032	Rack Mtg. Panel, 2 units		●
2160A-7033	Rack Mtg. Panel, 3 units		●
2160A-7016	J-Type Select PCB		●
2160A-7017	K-Type Select PCB		●
2160A-7019	E-Type Select PCB		●
2160A-7018	T-Type Select PCB		●
2160A-7012	R-Type Select PCB		●
2160A-7013	S-Type Select PCB		●
2160A-7014	B-Type Select PCB		●
2160A-7015	C-Type Select PCB		●
2160A-7022	Interface Cable		●
2161A	Multipoint Selector	○	
2162A	Digital Comparator	○	
–02	Digital Output Unit	○	
–04	Analog Output Unit	○	

○ = T-punched for insertion in Section 6 of this manual

● = Not T-punched

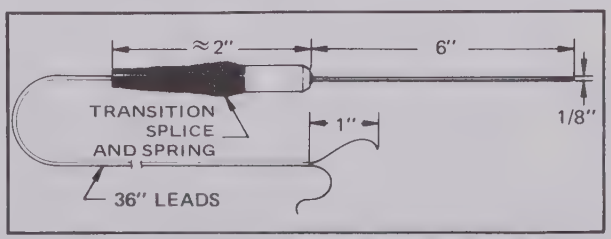


Figure 6-1. P20 SERIES THERMOCOUPLE PROBES

6-7. TYPE SELECT PCB's

6-8. A series of plug-in type select pcb's are available as accessories to allow the thermocouple compatibility of the 2160A to be changed by the user. The available pcb's are listed in Table 6-1, and the instructions necessary to interchange pcb's in the 2160A are given in Section 2 of this manual under Thermocouple Compatibility. Only one of the pcb's can be installed in the 2160A at any given time.

6-9. INTERFACE CABLE (2160A-7022)

6-10. The Interface Cable is a 6-foot, ribbon cable and 34-pin connector designed to interface either the Analog Output Unit (Option –04) or the Digital Output Unit (Option –02) with an external piece of equipment. The connector is polarized and mates with the rear-panel connector of the Analog/Digital Output Unit. The connections to the free end of the cable are completed, as necessary, to interface the external device. Refer to the instructions provided with the Analog/Digital Output Unit for pin assignments.

6-11. MODEL 2161A MULTIPOINT SELECTOR

6-12. The Model 2161A Multipoint Selector is a panel-mounting, manually-switched selector that allows 1-of-10 thermocouple probes (all of the same type) to function as the thermocouple input to the 2160A. When more than 10 inputs are involved, 2 or more 2161A's can be stacked in either a serial or parallel configuration.

6-13. MODEL 2162A DIGITAL COMPARATOR

6-14. The Model 2162A Digital Comparator is a panel-mounting, manually-set, single-limit comparator. Front-panel, thumb-wheel switches provide for the selection of high or low ($\geq$ or $\leq$), polarity and four limit digits. The resolution of the 2162A is $\pm 1^{\circ}$. A cable on the rear of the 2162A attaches to the back of the 2160A to provide the 2162A with both operating voltage and display data. When an out-of-limit reading occurs at the 2160A, the 2162A generates both a visual and an electrical indication, i.e., a front-panel LED is lit and a contact closure occurs. The contact closure is accessible through the 2162A's rear panel, and is electrically isolated from both the 2160A and the 2162A. Two 2162A's can be connected in parallel for multiple limit requirements.

6-15. DIGITAL OUTPUT UNIT, OPTION –02

6-16. The Digital Output Unit (Option –02) is a field installable pcb that mounts on the interior of the 2160A and provides a digital output which is equivalent to the displayed measurement data. The digital output is positive-true, TTL compatible and is presented in bcd, character-parallel format. All displayed characters are represented at the output. Output data is solicited by an External Trigger input and valid data is ensured by Busy and $\overline{\text{Busy}}$ outputs.

6-17. External connections to the Digital Output Unit are made through a 34-pin ribbon connector which is supplied with the pcb. The connector is compatible with Amphenol's 34-wire standard ribbon cable. A 6-foot ribbon cable and connector is available as an accessory and is described earlier in this section under Interface Cable.

6-18. ANALOG OUTPUT UNIT, OPTION –04

6-19. The Analog Output Unit is a field installable pcb assembly which provides the 2160A with a rear-panel analog output voltage proportional to the displayed measurement data. The output voltage is electrically isolated from the 2160A and covers a voltage range of –0.4 to +4V dc. Automatic polarity sensing is provided for both °C and °F measurements to ensure that the polarity of the output voltage agrees with the displayed polarity. Since the analog output terminals are isolated from the 2160A, the output voltage is referenced to the low terminal of the external recording device (voltmeter, strip-chart recorder, etc.).

6-20. External connections to the Analog Output Unit are made through a 34-pin ribbon connector which is supplied with the pcb. The connector is compatible with Amphenol's 34-wire standard ribbon cable. A 6-foot ribbon cable and connector is available as an accessory and is described earlier in this section under Interface Cable.

Model 2160-02 Digital Output Unit

602-1. INTRODUCTION

602-2. The Digital Output Unit (Option -02) is a field installable pcb that mounts on the interior of any one of the 2160A/2170A series of Digital Thermometer and provides a digital output which is equivalent to the displayed measurement data. The digital output is positive-true TTL compatible and is presented in bcd, character-parallel format. All displayed characters are represented at the output. Updated output data is available after each thermometer measurement cycle, and can be recorded in either of two operated modes; free-run or triggered operation. In both modes the trailing edge of a Busy/$\overline{\text{Busy}}$ output pulse is used to command the recorder. This pulse is generated at the end of each measurement cycle in the free-run mode. In the triggered mode this pulse is generated only after an external trigger input is received at the Digital Output Unit.

602-3. External connections to the Digital Output Unit are made through a 34-pin ribbon connector which is supplied with the pcb. The connector is compatible with Amphenol's 34-wire standard ribbon cable. A 6-foot ribbon cable and connector is available as an accessory (Model No. 2160A-7022).

602-4. SPECIFICATIONS

Digital I/O Logic - DTL, TTL compatible.
Logical "1" = 4.5 to + 5.5V dc
Logical "0" = 0 to + 0.5V dc

Available Data - - Four digits, polarity and function

Data Format - - BCD, positive true, character parallel

Isolation - - - I/O data is fully isolated to 300V dc or ac peak

Controls - - - External Trigger and External Trigger Enable

Output Flags - - Busy and $\overline{\text{Busy}}$

Compatibility - - Can be installed in any of the following digital thermometers: 2160A, 2165A, 2166A, 2168A, 2170A, 2175A, and 2176A.

602-5. INSTALLATION

602-6. The Digital Output Unit may be installed in any one of the 2160A/2170A series of digital thermometers. Two installation procedures follow. Use the one that applies to the model number of your thermometer.

602-7. Models 2160A and 2170A.

a. Disconnect the thermometer from line power.

b. Remove the rear panel and the thermometer assembly from the thermometer case. (two rear panel screws hold both in position).

c. Position the thermometer pcb assembly and the Digital Output Unit pcb as shown in Figure 602-1.

d. Carefully plug the Digital Output Unit's flex cable into the connector provided on the thermometer pcb. See Figure 602-1.

e. Determine the thermometers assigned temperature scale (°C or °F) and assign the same scale to the Digital Output Unit by installing a jumper

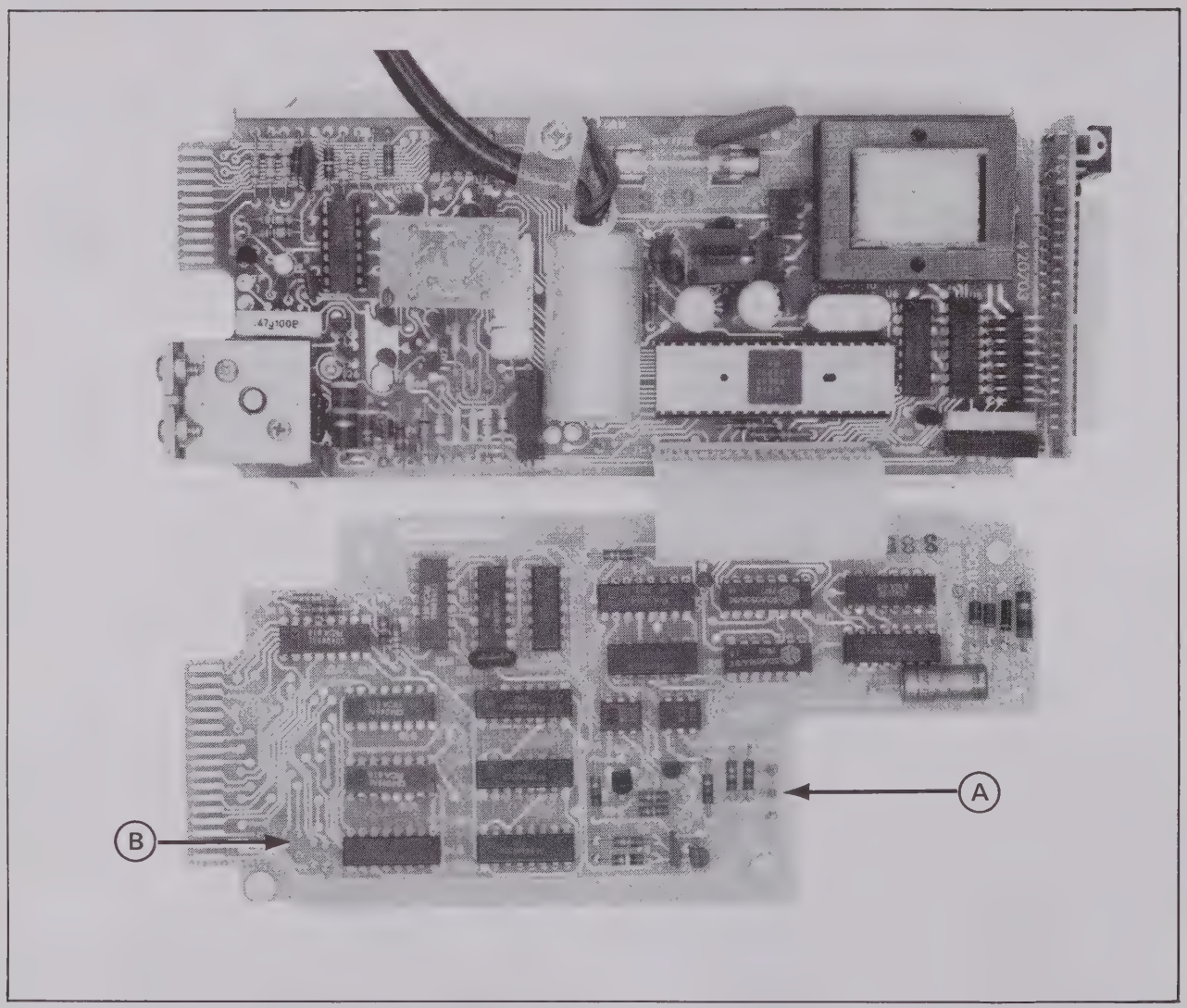


Figure 602-1
DIGITAL OUTPUT UNIT INSTALLATION DETAILS, 2160A/2170A

between the appropriate terminals (°C or °F) as shown in Figure 602-1 location A.

f. Refer to location B in Figure 602-1 and check the Digital Output Unit pcb to see if four jumpers are installed in that location. They must be installed if the pcb is being used in a Model 2170A, and removed if the pcb is being used in a Model 2160A. These jumpers are included as part of the mounting hardware.

g. Turn the Digital Output Unit pcb over so that it is face-down and on top of the thermometer pcb assembly.

h. Align the two pcb's with the support rails at the rear of the thermometer case (main pcb on bottom and Digital Output Unit pcb on top), and slide them into the case.

i. Slide one sheet of mylar insulation under the main pcb and one on top of the Digital Output Unit (one sheet is supplied with the Digital Output Unit and the other is part of the 2160A/2170A).

j. Position and secure the thermometer's rear panel using the screws that were removed in step b of this procedure.

602-8. Models 2165A, 2166A, 2168A, 2175A, 2176A.

a. Disconnect the thermometer from line power.

b. Remove the center, rear-panel screw from the thermometer and separate the instrument from the case.

c. Refer to Figure 602-2, location B and remove the two screws indicated from the thermometer pcb.

d. Position the Digital Output Unit over the thermometer pcb as shown in Figure 602-2 and carefully plug the Digital Output Unit's flex cable into the connector provided on the thermometer pcb assembly.

e. Using the hardware supplied with the Digital Output Unit (screws, stand-offs, nuts, and washers) mount the Digital Output Unit pcb to the thermometer pcb. Hardware installation details are shown in Figure 602-2 locations B and C.

NOTE

Insure that all four screws are properly tightened. The two in location C are used to make electrical connections between the pcb's.

f. Check the Digital Output Unit pcb to ensure there is no jumper installed at location A as shown in Figure 602-2. Remove any jumper that may be present.

g. Refer to location D in Figure 602-2 and check the Digital Output Unit pcb to see if four jumper wires are installed. They must be installed if the pcb is being used in a Model 2175A or 2176A, and removed if the pcb is being used in a Model 2165A, 2166A or 2168A.

h. Install the thermometer and Digital Output Unit pcb's in the thermometer case, and secure them using the rear-panel screw removed in step b of this procedure.

602-9. OPERATING NOTES

602-10. The following paragraphs describe various conditions that should be considered before attempting to operate the Digital Output Unit.

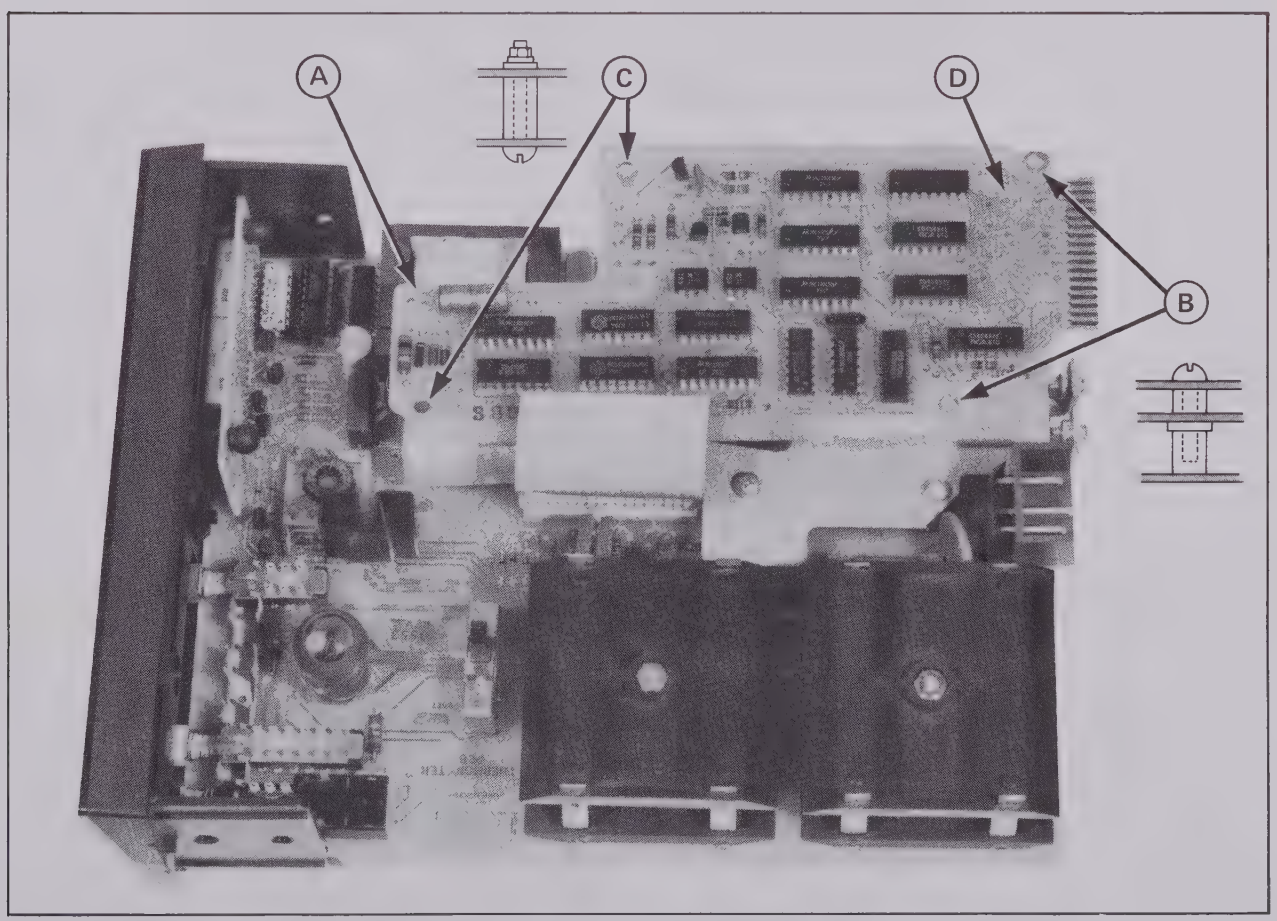


Figure 602-2
DIGITAL OUTPUT UNIT INSTALLATION DETAILS, 2165A, 2166A, 2168A, 2175A and 2176A

602-11. Output Cable Connections

602-12. The Digital Output Unit is supplied with an output connector that is compatible with Amphenol's standard 34-pin ribbon cable. Input/Output signal and pin assignment are defined in Table 602-1. All inputs/outputs are DTL/TTL compatible and positive-true logic is employed in generating all output data.

Table 602-1.
OUTPUT CONNECTOR PIN IDENTIFICATION

PIN	SIGNAL NAME	DESCRIPTION
1 2	+5V dc Logic Common	Isolated +5V dc output. 1 mA maximum.
3	Busy	Busy when high
4	$\overline{\text{Busy}}$	Busy when low
5	Trigger	High-to-low transition (PW≥500ms)
6	Enable	Enable trigger = Low, Inhibit = High
7	Not Used	
8	$\overline{\text{Polarity}}$	High = +, Low = –
9 10 11 12	Not Used Not Used Not Used Not Used	
13	Overload	High = O.L., Low = Normal
14	Polarity	High = –, Low = +
15 16	Y1 (2) Z1 (1)	Most Significant Decade #1
17 18 19 20	W2 (8) X2 (4) Y2 (2) Z2 (1)	Decode #2
21 22 23 24	W3 (8) X3 (4) Y3 (2) Z3 (1)	Decode #3
25 26 27 28	W4 (8) X4 (4) Y4 (2) Z4 (1)	Decode #4
29 30 31 32	W5 (8) X5 (4) Y5 (2) Z5 (1)	Decode #5 2170A, 2175A and 2176A Only
33 34	°F °C	Temperature Scale

602-13. Free-Run Operation

602-14. In the free-run mode, the Digital Output Unit is updated at the end of each measurement cycle, and a command to operate an external printer (recorder) is issued. Free-run operation is enabled by leaving pins 5 (External Trigger) and 6 (Enable) open (pull-up resistors are provided) or holding them high if external control logic is employed. Under these conditions, a Busy and $\overline{\text{Busy}}$ pulse (pins 3 and 4, respectively) is generated at the end of each measurement cycle to indicate that the Digital Output Unit is updating its output registers. During this period, erroneous data will be obtained if the printer is commanded. To preclude this possibility, the trailing edge of either the Busy or $\overline{\text{Busy}}$ pulse (depending on printer requirements) should be used to trigger the printer. Output data is updated at the rate of approximately 2.5 readings per second.

602-15. Triggered Operation

602-16. In the triggered mode, the Digital Output Unit is updated by the next full measurement cycle following an External Trigger, and a command to operate an external printer (recorder) is issued. Triggered operation is enabled by holding the Enable input (pin 6) continuously low and providing an External Trigger input (high-to-low transition) on pin 6. After the trigger is received, Busy and $\overline{\text{Busy}}$ pulses are generated at the end of the next complete measurement cycle to indicate that the Digital Output Unit is updating its output registers. During this period, erroneous data will be obtained if the printer is commanded. To preclude this possibility, the trailing edge of either the Busy or $\overline{\text{Busy}}$ pulse (depending on printer requirements) should be used to trigger the printer. Output data will be updated and printed only after an External Trigger input is received.

602-17. PCB Jumper Requirements

602-18. FIFTH DECADE JUMPERS

602-19. The Digital Output Unit is compatible with both the 2160A and 2170A series of digital thermometers. However, since the 2170A series offers an extra decade of resolution, jumper terminals are provided on the pcb so that this fifth decade can be added or deleted, as necessary. Four jumpers are involved in the fifth decade (see location D in Figure 602-2), and all should be installed when the Digital Output Unit is used with the Model 2170A, 2175A or 2176A Digital Thermometers. Similarly, the jumpers should be removed for operation with a Model 2160A, 2165A, 2166A, or 2168A.

602-20. **TEMPERATURE SCALE JUMPERS**

602-21. When the Digital Output Unit is used with the Model 2160A or 2170A Digital Thermometer, the appropriate temperature scale (°C or °F) must be specified on the Digital Output Unit pcb by installing a jumper at location A as shown in Figure 602-1. The jumper must be removed from both the °C and °F location when the Digital Output Unit is being operated with the Model 2176A, 2166A, 2168A, 2175A or 2176A Digital Thermometer. These units are equipped with a front-panel temperature-scale-select switch (°C or °F) that automatically provides the Digital Output Unit with the proper temperature scale information.

602-23. Decimal Point

602-23. Decimal point information for digital thermometers with 0.2° resolution (2170A series) is not processed by the Digital Output Unit. Instead, since the decimal point is fixed (i.e., always preceeds the LSD), it is the user's responsibility to generate decimal point information for use by the printer. This is generally accomplished by fixing the appropriate printer input line at either a high or low level, as required. If the printer is used to record multiplexed data, the decimal point input should preceed the multiplexer.

602-24. OPERATION

602-25. Once installed, the Digital Output Unit requires no operator attention other than ensuring that the digital thermometer, external printer, and external trigger circuitry (if any) is properly connected, energized and operational.

602-26. THEORY OF OPERATION

602-27. The function of the Digital Output Unit is to isolate, deserialize and store digital measurement data from a 2160A/2170A series Digital Thermometer for use inproviding measurement data to a digital printer (recorder). Output data is presented in a bcd, positive-true character-parallel format and is DTL/TTL compatible. It can be updated automatically at the end of each digital thermometer measurement cycle, or solicited and updated on command using an external trigger feature. A simplified block diagram of the Digital Output Unit is given in Figure 602-3. A detailed schematic and timing diagram of the Digital Output Unit is shown in Figure 602-4.

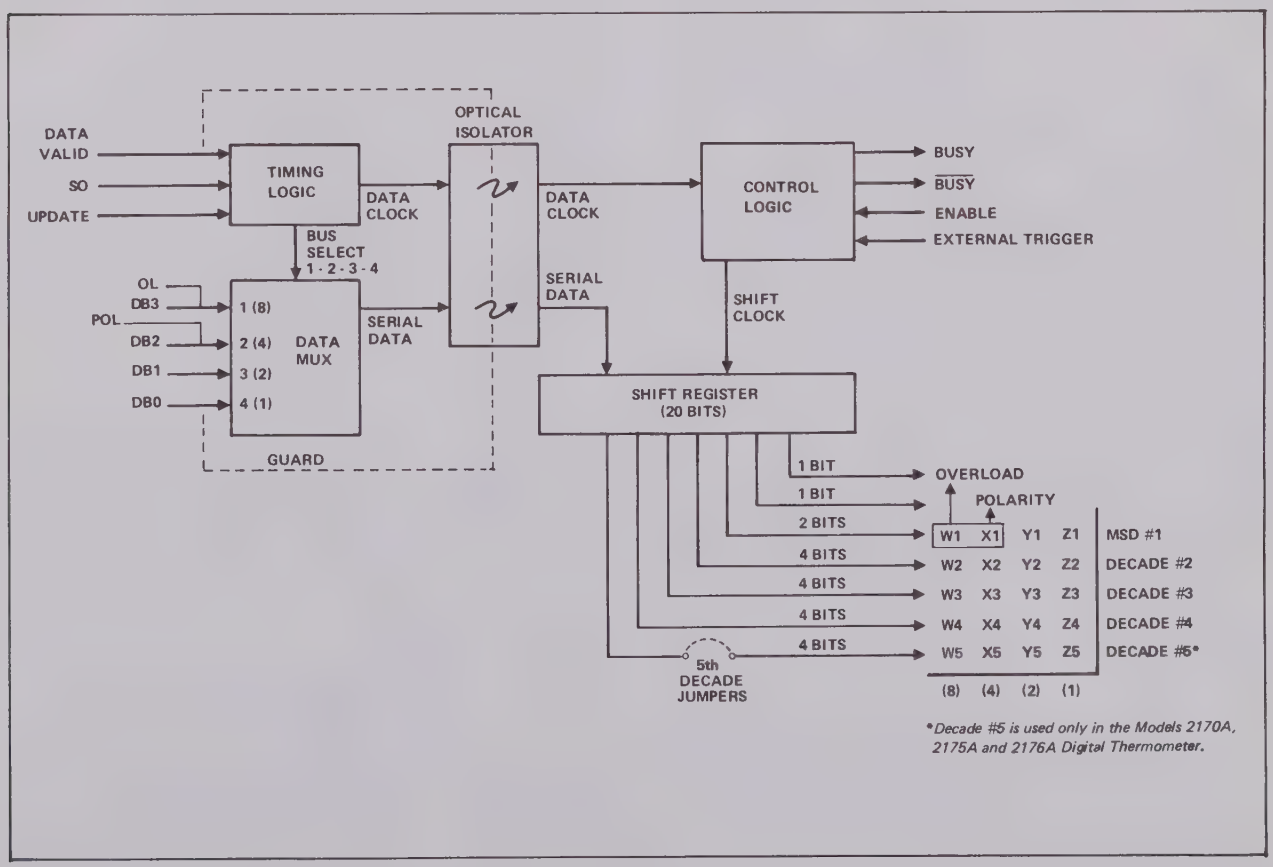


Figure 602-3
DIGITAL OUTPUT UNIT SIMPLIFIED BLOCK DIAGRAM

602-28. Numeric measurement data from the thermometer is transmitted (on a continuous basis) to the Digital Output Unit in bit-parallel character-serial format. It is received on a four-bit data bus (DB0 thru DB3) and is accompanied by a series of timing pulses that are used to control and synchronize the overall operation of the Digital Output Unit. As each serial character is placed on the data bus, its presence and validity is signified by the generation of a data valid (DV) pulse. Similarly the beginning of a new measurement word (five serial characters) is marked by the generation of a Strobe Out (SO) pulse. Since, measurement data is continuously repeated on the data bus, and each measurement word occurs many times during a measurement cycle, a third pulse is required to ensure that the Digital Output Unit can be updated only at the end of a measurement cycle. This is accomplished by an Update pulse which occurs at the end of each measurement cycle and lasts for the duration of the next five DV pulses. Each of these pulses (DV, SO and Update) are shown in the timing diagram in Figure 602-4.

602-29. In addition to numeric data, the digital thermometer also transmits polarity and overload information with each measurement word. This data is provided to the Digital Output Unit as two separate inputs and each is present for the duration of the measurement cycle (i.e., both inputs are updated at the end of each measurement cycle).

602-30. The transfer of measurement data from the digital thermometer to the Digital Output Unit begins when the Update pulse goes high, and continues until the measurement word has been repeated four times. As the word is read the first time, the timing logic enables a data multiplexer (MUX) to serially couple the most-significant-bit (8) from each of the five measurement characters across the guard. These serial bits are then presented to the data input of a 20-bit shift register. The second, third and fourth readings serialize the 4, 2, and 1 bits respectively, from each of the five measurement words and couples them across the guard to the shift register input. During this entire serializing process, the multiplexer also enables the Data Valid pulse to be coupled across the guard. As each data bit is presented to the shift register, the Data Valid pulse clocks it into the shift register. At the end of the fourth reading the multiplexer is disabled to inhibit subsequent measurement data and Data Valid pulses from crossing the guard. As a result the entire measurement word (five 4-bit characters) is stored in the shift register, and is available in parallel format for use by an external printer.

NOTE

Since the most-significant-digit (MSD) of the five character measurement word never exceeds three, overload and polarity information is coupled across the guard as the 8 and 4 bits of the MSD. The SO pulse is used to gate this information to the multiplexer during the first data valid period of the first and second readings. See table of output data in Figure 602-3.

602-31. During the data transfer process, the control logic detects presence of the Data Valid pulse and generates a Busy and $\overline{\text{Busy}}$ pulse at the output connector. These pulses, when active, indicate that the shift register is being loaded and output data is, therefore, invalid. Normally the trailing edge of either the Busy or $\overline{\text{Busy}}$ pulse is used as a print command to trigger the external printer.

602-32. To this point, the operation described is for the free-run mode where the shift register and, therefore, the output is updated at the end of each measurement cycle. A second operating mode, triggered operation, is possible, i.e., output data is only updated on command. This mode is enabled by holding the Enable input low. With Enable low, the Data Valid pulse is inhibited from reaching the shift register and the output data remains unchanged regardless of changes in measurement data. However, if a negative-going External Trigger is applied to the control logic, the register will be updated at the end of the next measurement cycle. Trigger timing is not critical since the control logic insures that a measurement cannot be initiated during the data transfer period. Instead, the trigger is stored and used to solicit data during the next data transfer period.

602-33. The 8-4-2-1 bits of the fifth decade (LSD) of measurement data are not valid when the Digital Output Unit is used with a Model 2160A, 2165A, 2166A or 2166A Digital Thermometer. Therefore, plug-in jumpers have been provided on the pcb so that the fifth decade of measurement data can be isolated from the output connector. These jumpers should only be installed when the Digital Output Unit is being used with a Model 2170A, 2175A, or 2176A Digital Thermometer.

602-34. CALIBRATION

602-35. The Digital Output Unit does not require calibration. If the unit fails to operate, check to ensure proper cable connections between the unit and the digital thermometer, and the external printer. Isolate the problem to the Digital Output Unit by checking the overall operation of the digital thermometer. If the thermometer operates properly, the problem is either on the Digital Output Unit pcb or the external printer.

602-36. LIST OF REPLACEABLE PARTS

602-37. A list of replaceable parts for the Digital Output Unit is given in Table 602-2. Refer to Section 5 of the digital thermometer manual for ordering information.

Table 602-2. LIST OF REPLACEABLE PARTS

REF DESIG OR ITEM NO.	DESCRIPTION	FLUKE STOCK NO.	MFG FED SPLY CDE	MFG PART. NO. OR TYPE	TOT QTY	REC QTY	USE CDE
	FINAL ASSEMBLY, DIGITAL OUTPUT UNIT, MODEL 2160A-02						
A1	Digital Output Unit PCB Assembly (2160A-4030)	415950	89536	415950	1		
	Insulator, mylar	415513	89536	415513	1		
	Spacer, aluminum, 0.5 inch	102616	89536	102616	2		
	Spacer, aluminum, 1.063 in	201020	89536	291020	2		
	Connector, 34-pin	424242	89536	424242	1		
	DIGITAL OUTPUT UNIT PCB ASSEMBLY (2160A-4030) FIGURE 602-4						
C1	Cap, cer, 0.01 μF ±20%, 100V	149153	56289	C023B101F103M	1		
C2	Cap, mica, 33 pF ±5%, 500V	160317	72136	DM15E331J	1		
C3	Cap, elect, 220 μF –10/+50%, 10V	236935	73445	ET221X010A5	1	1	
C4	Cap, Ta, 10 μF ±20%, 15V	193623	56289	196D106X0015A1	1		
CR2, CR3	Diode, Si, 1A	368738	04713	1N4004	2	1	
P1	Cable and connector assembly	418764	00779	1-86942-7	1		
Q1, Q2, Q3	Xstr, Si, NPN	218396	04713	2N3904	3	1	
R1, R2	Res, comp, 20K ±5%, ¼ W	221614	01121	CB2035	2		
R3, R8	Res, comp 2K ±5%, ¼ W	202879	01121	CB2025	2		
R4	Res, comp, 100K ±5%, ¼ W	148189	01121	CB1045	1		
R5	Res, comp 15K ±5%, ¼ W	148114	01121	CB1535	1		
R6, R7	Res, comp 16K ±5%, ¼ W	221606	01121	CB1635	2		
R9, R11	Res, comp, 33K ±5%, ¼ W	148155	01121	CB3335	2		
R10, R12	Res, comp, 10K ±5%, ¼ W	148106	01121	CB1035	2		
R13	Res, comp 100 ±5%, ½ W	108100	01121	EB1015	1		
R14	Res, comp, 51K ±5%, ¼ W	193334	01121	CB5135	1		
U1, U8, U9, U10	IC, C-MOS, dual four-bit shift register	340125	04713	MC14015CP	4	1	
U2	IC, C-MOS, qual bilateral switch	363838	95303	CD4016AE	1	1	
U3	IC, C-MOS, quad and-or select gate	419010	95303	CD4019AE	1	1	
U4	IC, C-MOS, dual four-input NOR gate	363820	04713	MC14002CP	1	1	
U5, U13, thru U17	IC, C-MOS, hex buffer/inverter	381848	05303	CD4049AE	6	1	
U6, U7	IC, isolator, optically coupled	380014	50522	MCT2	2	1	
U11	IC, MOS, dual D-type flip-flop	340117	04713	MC14013L	1	1	
U12	IC, C-MOS, qual two input NOR gate	355172	04713	MC14001P	1	1	
U18	IC, C-MOS, hex buffer/inverter	381830	95303	CD4050AE	1	1	
VR1	Diode, zener, 5.6V	277236	04713	IN752A	1	1	
	Connector female, 1-pin	376418	22526	75060-007	1		

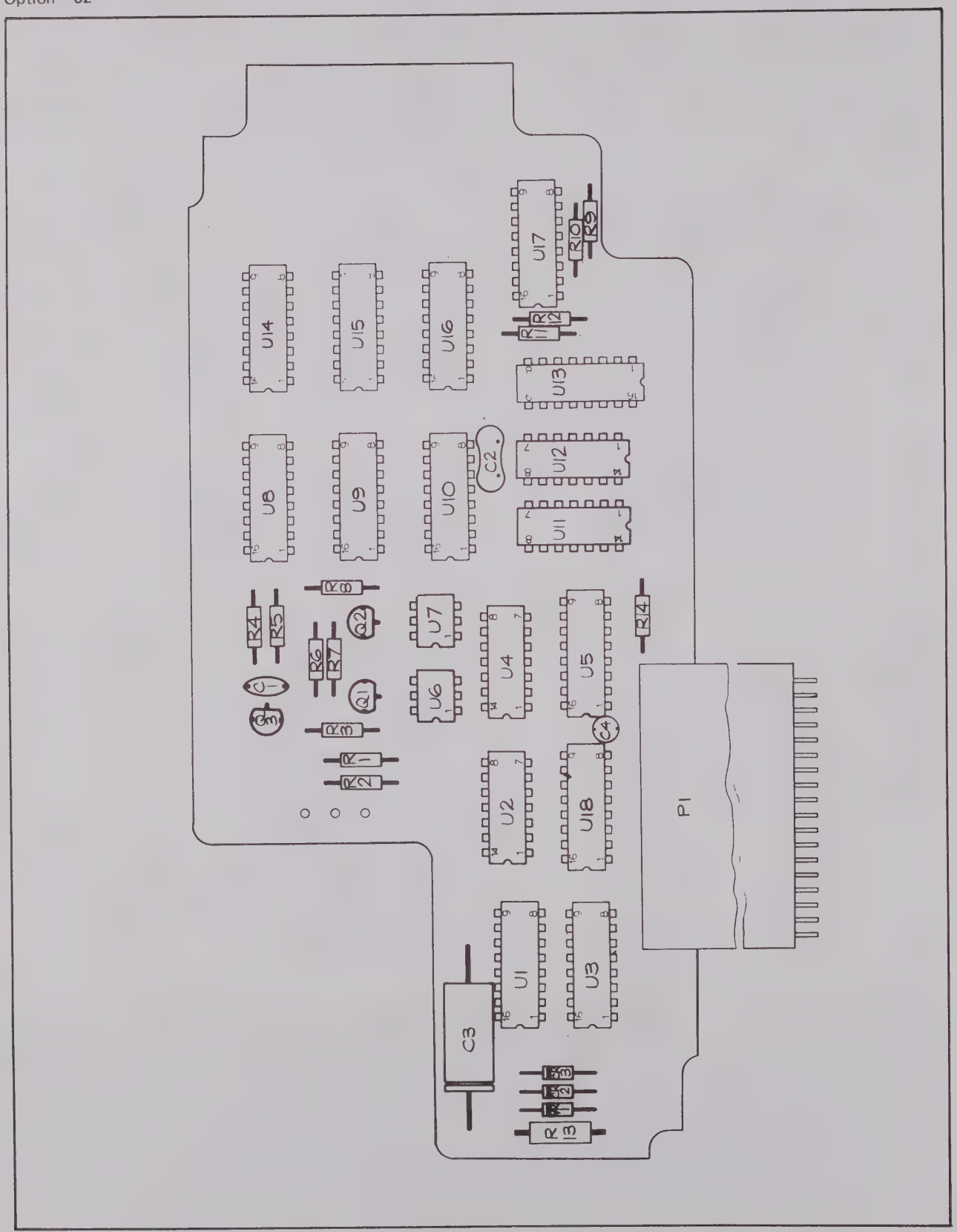


Figure 602-4 (1 of 2).
DIGITAL OUTPUT UNIT PCB ASSEMBLY (2160A-1030)

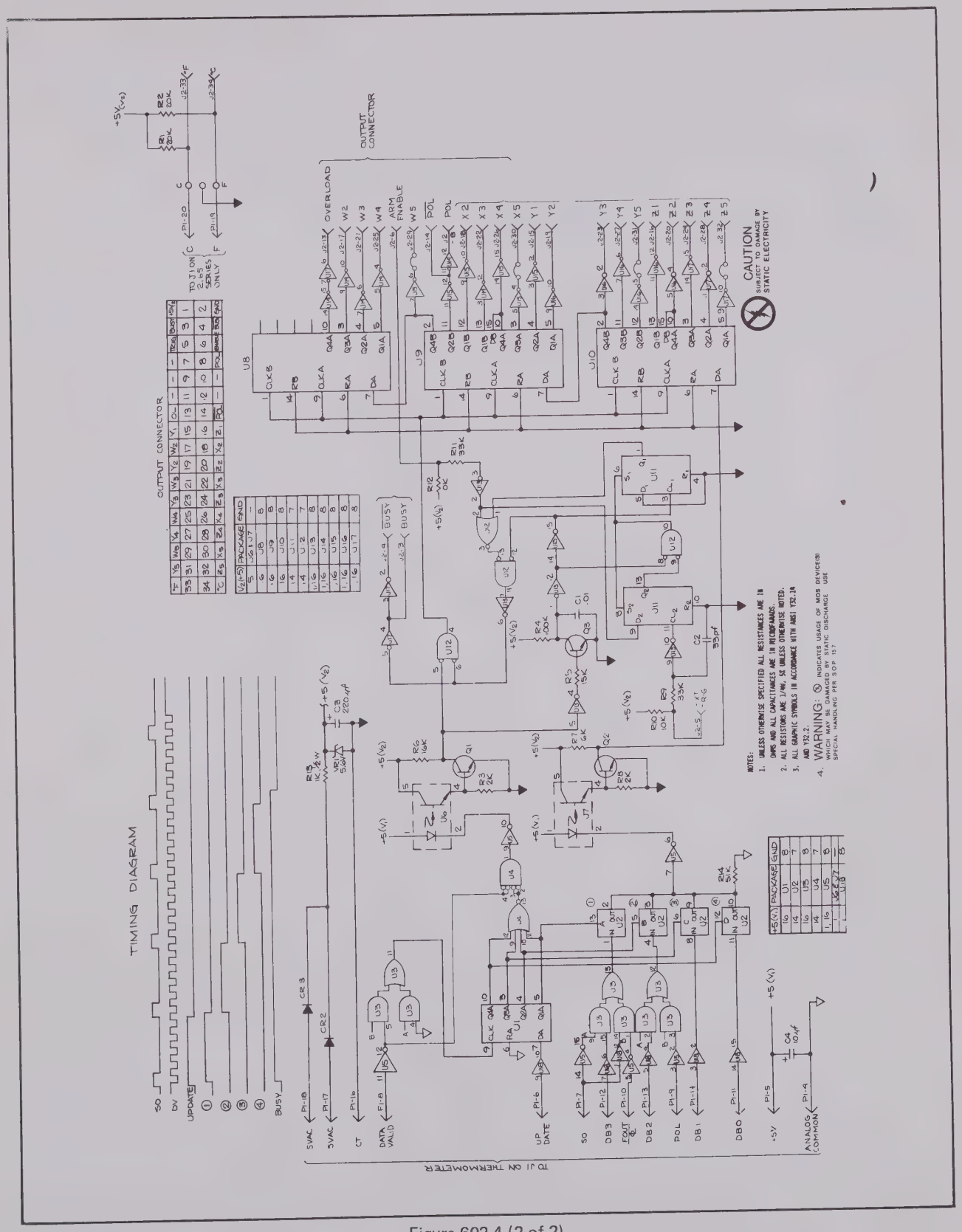


Figure 602-4 (2 of 2).
DIGITAL OUTPUT UNIT PCB ASSEMBLY (2160A-1030)

Section 7
General Information

7-1. This section of the manual contains generalized user information as well as supplemental information to the Lists of Replaceable parts contained in Section 5. The following information is presented in this section:

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Table 7-1. LIST OF ABBREVIATIONS AND SYMBOLS

A or amp	ampere
ac	alternating current
af	audio frequency
a/d	analog-to-digital
assy	assembly
AWG	american wire gauge
B	bel
bcd	binary coded decimal
^{o}C	Celsius
cap	capacitor
ccw	counterclockwise
cer	ceramic
cermet	ceramic to metal(seal)
ckt	circuit
cm	centimeter
cmrr	common mode rejection ratio
comp	composition
cont	continue
crt	cathode-ray tube
cw	clockwise
d/a	digital-to-analog
dac	digital-to-analog converter
dB	decibel
dc	direct current
dmm	digital multimeter
dvm	digital voltmeter
elect	electrolytic
ext	external
F	farad
^{o}F	Fahrenheit
FET	Field-effect transistor
ff	flip-flop
freq	frequency
FSN	federal stock number
g	gram
G	giga (10^{9})
gd	guard
Ge	germanium
GHz	gigahertz
gmv	guaranteed minimum value
gnd	ground
H	henry
hd	heavy duty
hf	high frequency
Hz	hertz
IC	integrated circuit
if	intermediate frequency
in	inch(es)
intl	internal
I/O	input/output
k	kilo (10^{3})
kHz	kilohertz
kΩ	kilohm(s)
kV	kilovolt(s)
lf	low frequency
LED	light-emitting diode
LSB	least significant bit
LSD	least significant digit
M	mega (10^{6})
m	milli (10^{-3})
mA	milliampere(s)
max	maximum
mf	metal film
MHz	megahertz
min	minimum
mm	millimeter
ms	millisecond
MSB	most significant bit
MSD	most significant digit
MTBF	mean time between failures
MTTR	mean time to repair
mV	millivolt(s)
mv	multivibrator
MΩ	megohm(s)
n	nano (10^{-9})
na	not applicable
NC	normally closed
(–) or neg	negative
NO	normally open
ns	nanosecond
opnl ampl	operational amplifier
p	pico (10^{-12})
para	paragraph
pcb	printed circuit board
pF	picofarad
pn	part number
(+) or pos	positive
pot	potentiometer
p-p	peak-to-peak
ppm	parts per million
PROM	programmable read-only memory
psi	pound-force per square inch
RAM	random-access memory
rf	radio frequency
rms	root mean square
ROM	read-only memory
s or sec	second (time)
scope	oscilloscope
SH	shield
Si	silicon
serno	serial number
sr	shift register
Ta	tantalum
tb	terminal board
tc	temperature coefficient or temperature compensating
tcxo	temperature compensated crystal oscillator
tp	test point
u or μ	micro (10^{-6})
uhf	ultra high frequency
us or μs	microsecond(s) (10^{-6})
uut	unit under test
V	volt
v	voltage
var	variable
vco	voltage controlled oscillator
vhf	very high frequency
vlf	very low frequency
W	watt(s)
ww	wire wound
xfmr	transformer
xstr	transistor
xtal	crystal
xtlo	crystal oscillator
Ω	ohm(s)
μ	micro (10^{-6})

Table 7-2. FEDERAL SUPPLY CODES FOR MANUFACTURERS

00213
Nytronics Comp. Group Inc.
Subsidiary of Nytronics Inc.
Formerly Sage Electronics
Rochester, New York

00327
Welwyn International, Inc.
Westlake, Ohio

00656
Aerovox Corp.
New Bedford, Massachusetts

00686
Film Capacitors, Inc.
Passaic, New Jersey

00779
AMP Inc.
Harrisberg, Pennsylvania

01121
Allen-Bradley Co.
Milwaukee, Wisconsin

01281
TRW Electronic Comp.
Semiconductor Operations
Lawndale, California

01295
Texas Instruments, Inc.
Semiconductor Group
Dallas, Texas

01537
Motorola Communications &
Electronics Inc.
Franklin Park, Illinois

01686
RCL Electronics Inc.
Manchester, New Hampshire

01730
Replaced by 73586

01884 - use 56289
Sprague Electric Co.
Dearborn Electronic Div.
Lockwood, Florida

02114
Ferroxcube Corp.
Saugerties, New York

02131
General Instrument Corp.
Harris ASW Div.
Westwood, Maine

02395
Rason Mfg. Co.
Brooklyn, New York

02533
Snelgrove, C.R. Co., Ltd.
Don Mills, Ontario, Canada
M3B 1M2

02606
Fenwal Labs
Div. of Travenal Labs.
Morton Grove, Illinois

02660
Bunker Ramo Corp., Conn Div.
Formerly Amphenol-Borg
Electric Corp.
Broadview, Illinois

02799
Areo Capacitors, Inc.
Chatsworth, California

03508
General Electric Co.
Semiconductor Products
Syracuse, New York

03614
Replaced by 71400

03651
Replaced by 44655

03797
Eldema Div.
Genisco Technology Corp.
Compton, California

03877
Transistron Electronic Corp.
Wakefield, Massachusetts

03888
KDI Pyrofilm Corp.
Whippany, New Jersey

03911
Clairex Electronics Div.
Clairex Corp.
Mt. Vernon, New York

03980
Muirhead Inc.
Mountainside, New Jersey

04009
Arrow Hart Inc.
Hartford, Connecticut

04062
Replaced by 72136

04202
Replaced by 81312

04217
Essex International Inc.
Wire & Cable Div.
Anaheim, California

04221
Aemco, Div. of
Midtex Inc.
Mankato, Minnesota

04222
AVX Ceramics Div.
AVX Corp.
Myrtle Beach, Florida

04423
Telonic Industries
Laguna Beach, California

04645
Replaced by 75376

04713
Motorola Inc. Semiconductor
Products
Phoenix, Arizona

04946
Standard Wire & Cable
Los Angeles, California

05082
Replaced by 94988

05236
Jonathan Mfg. Co.
Fullerton, California

05245
Components Corp. now
Corcom, Inc.
Chicago, Illinois

05277
Westinghouse Electric Corp.
Semiconductor Div.
Youngwood, Pennsylvania

05278
Replaced by 43543

05279
Southwest Machine &
Plastic Co.
Glendora, California

05397
Union Carbide Corp.
Materials Systems Div.
New York, New York

05571 - use 56289
Sprague Electric Co.
Pacific Div.
Los Angeles, California

05574
Viking Industries
Chatsworth, California

05704
Replaced by 16258

05820
Wakefield Engineering Inc.
Wakefield, Massachusetts

06001
General Electric Co.
Electronic Capacitor &
Battery Products Dept.
Columbia, South Carolina

06136
Replaced by 63743

06383
Panduit Corp.
Tinley Park, Illinois

06473
Bunker Ramo Corp.
Amphenol SAMS Div.
Chatsworth, California

06555
Beede Electrical Instrument Co.
Penacook, New Hampshire

06739
Electron Corp.
Littleton, Colorado

06743
Clevite Corp.
Cleveland, Ohio

06751
Components, Inc. Semcor Div.
Phoenix, Arizona

06860
Gould Automotive Div.
City of Industry, California

06961
Vernitron Corp., Piezo
Electric Div.
Formerly Clevite Corp., Piezo
Electric Div.
Bedford, Ohio

06980
Eimac Div.
Varian Associates
San Carlos, California

07047
Ross Milton, Co., The
South Hampton, Pennsylvania

07115
Replaced by 14674

07138
Westinghouse Electric Corp.,
Electronic Tube Division
Horsehead, New York

07233
TRW Electronic Components
Cinch Graphic
City of Industry, California

07256
Silicon Transistor Corp.
Div. of BBF Group Inc.
Chelmsford, MA

07261
Aumet Corp.
Culver City, California

07263
Fairchild Semiconductor
Div. of Fairchild Camera
& Instrument Corp.
Mountain View, California

07344
Bircher Co., Inc.
Rochester, New York

07597
Burndy Corp.
Tape/Cable Div.
Rochester, New York

07792
Lerma Engineering Corp.
Northampton, Massachusetts

07910
Teledyne Semiconductor
Formerly Continental Device
Hawthorne, California

07933 - use 49956
Raytheon Co.
Semiconductor Div. HQ
Mountain View, California

08225
Industro Transistor Corp.
Long Island City, New York

08261
Spectra Strip Corp.
Garden Grove, California

08530
Reliance Mica Corp.
Brooklyn, New York

08806
General Electric Co.
Miniature Lamp Products Dept.
Cleveland, Ohio

08863
Nylomatic Corp.
Norrisville, Pennsylvania

08988 - use 53085
Skottie Electronics Inc.
Archbald, Pennsylvania

09214
G.E. Co. Semi-Conductor
Products Dept.
Power Semi-Conductor
Products OPN Sec.
Auburn, New York

09353
C and K Components
Watertown, Massachusetts

09423
Scientific Components, Inc.
Santa Barbara, California

09922
Burndy Corp.
Norwalk, Connecticut

09969
Dale Electronics Inc.
Yankton, S. Dakota

10059
Barker Engineering Corp.
Formerly Amerace, Amerace
ESNA Corp.
Kenilworth, New Jersey

11236
CTS of Berne
Berne, Indiana

11237
CTS Keene Inc.
Paso Robles, California

11358
CBS Electronic Div.
Columbia Broadcasting System
Newburyport, MN

11403
Best Products Co.
Chicago, Illinois

11503
Keystone Columbia Inc.
Warren, Michigan

11532
Teledyne Relays
Hawthorne, California

Table 7-2. FEDERAL SUPPLY CODES FOR MANUFACTURERS (Continued)

11711
General Instrument Corp
Rectifier Division
Hickville, New York

11726
Qualidyne Corp.
Santa Clara, California

12014
Chicago Rivet & Machine Co.
Bellwood, Illinois

12040
National Semiconductor Corp.
Danburry, Connecticut

12060
Diodes, Inc.
Chatsworth, California

12136
Philadelphia Handle Co.
Camden, New Jersey

12300
Potter-Brumfield Division
AMF Canada LTD.
Guelph, Onatrio, Canada

12323
Presin Co., Inc.
Shelton, Connecticut

12327
Freeway Corp. formerly
Freeway Washer & Stamping Co.
Cleveland, Ohio

12443
Budd Co. The, Polychem Products
Plastic Products Div.
Bridgeport, PA

12615
U.S. Terminals Inc.
Cincinnati, Ohio

12617
Hamlin Inc.
Lake Mills, Wisconsin

12697
Clarostat Mfg. Co.
Dover, New Hampshire

12749
James Electronics
Chicago, Illinois

12856
Micrometals
Sierra Madre, California

12954
Dickson Electronics Corp.
Scottsdale, Arizona

12969
Unitrode Corp.
Watertown, Massachusetts

13103
Thermalloy Co., Inc.
Dallas, Texas

13327
Solitron Devices Inc.
Tappan, New York

13511
Amphenol Cadre Div.
Bunker-Ramo Corp.
Los Gatos, California

13606 - use 56289
Sprague Electric Co.
Transistor Div.
Concord, New Hampshire

13839
Replaced by 23732

14099
Semtech Corp.
Newbury Park, California

14140
Edison Electronic Div.
Mc Gray-Edison Co.
Manchester, New Hampshire

14193
Cal-R-Inc. formerly
California Resistor, Corp.
Santa Monica, California

14298
American Components, Inc.
an Insilco Co.
Conshohocken, Pennsylvania

14655
Cornell-Dublier Electronics
Division of Federal Pacific
Electric Co. Govt. Control Dept.
Newark, New Jersey

14752
Electro Cube Inc.
San Gabriel, California

14869
Replaced by 96853

14936
General Instrument Corp.
Semi Conductor Products Group
Hicksville, New York

15636
Elec-Trol Inc.
Saugus, California

15801
Fenwal Electronics Inc.
Div. of Kidde Walter and Co., Inc.
Framingham, Massachusetts

15818
Teledyne Semiconductors, formerly
Amelco Semiconductor
Mountain View, California

15849
Litton Systems Inc. Useco Div.
formerly Useco Inc.
Van Nuys, California

15898
International Business
Machines Corp.
Essex Junction, Vermont

15909
Replaced by 14140

16258
Space-Lok Inc.
Burbank, California

16299
Corning Glass
Electronic Components Div.
Raleigh, North Carolina

16332
Replaced by 28478

16473
Cambridge Scientific Ind.
Div. of Chemed Corporation
Cambridge, Maryland

16742
Paramount Plastics Fabricators, Inc.
Downey, California

16758
Delco Electronics
Div. of General Motors Corp.
Kokomo, Indiana

17001
Replaced by 71468

17069
Circuit Structures Lab.
Burbank, California

17338
High Pressure Eng. Co., Inc.
Oklahoma City, Oklahoma

17545
Atlantic Semiconductors, Inc.
Asbury Park, New Jersey

17856
Siliconix, Inc.
Santa Clara, California

17870
Replaced by 14140

18178
Vactec Inc.
Maryland Heights, Missouri

18324
Signetics Corp.
Sunnyvale, California

18612
Vishay Resistor Products Div.
Vishay Intertechnology Inc.
Malvern, Pennsylvania

18736
Voltronics Corp.
Hanover, New Jersey

18927
G T E Sylvania Inc.
Precision Material Group
Parts Division
Titusville, Pennsylvania

19451
Perine Machinery & Supply Co.
Seattle, Washington

19701
Electro-Midland Corp.
Mepco-Electra Inc.
Mineral Wells, Texas

20584
Enochs Mfg. Inc.
Indianapolis, Indiana

20891
Self-Organizing Systems, Inc.
Dallas, Texas

21604
Buckeye Stamping Co.
Columbus, Ohio

21845
Solitron Devices Inc.
Transistor Division
Riveria Beach, Florida

22767
ITT Semiconductors
Palo Alto, California

23050
Product Comp. Corp.
Mount Vernon, New York

23732
Tracor Inc.
Rockville, Maryland

23880
Stanford Applied Engrng.
Santa Clara, California

23936
Pamotor Div., Wm. J. Purdy Co.
Burlingame, California

24248
Replaced by 94222

24355
Analog Devices Inc.
Norwood, Massachusetts

24655
General Radio
Concord, Massachusetts

24759
Lenox-Fugle Electronics Inc.
South Plainfield, New Jersey

25088
Siemen Corp.
Isilen, New Jersey

25403
Amperex Electronic Corp.
Semiconductor &
Micro-Circuits Div.
Slatersville, Rhode Island

27014
National Semiconductor Corp.
Santa Clara, California

27264
Molex Products
Downers Grove, Illinois

28213
Minnesota Mining & Mfg. Co.
Consumer Products Div.
St. Paul, Minnesota

28425
Serv-/-Link formerly
Bohannan Industries
Fort Worth, Texas

28478
Deltrol Controls Div.
Deltrol Corporation
Milwaukee, Wisconsin

28480
Hewlett Packard Co. Corporate H.Q.
Palo Alto, California

28520
Heyman Mfg. Co.
Kenilworth, New Jersey

29083
Monsanto, Co., Inc.
Santa Clara, California

29604
Stackpole Components Co.
Raleigh, North Carolina

30148
A B Enterprise Inc.
Ahoskie, North Carolina

30323
Illinois Tool Works, Inc.
Chicago, Illinois

31091
Optimax Inc.
Colmar, Pennsylvania

32539
Mura Corp.
Great Neck, New York

32767
Griffith Plastic Corp.
Burlingame, California

32879
Advanced Mechanical Components
Northridge, California

32897
Erie Technological Products, Inc.
Frequency Control Div.
Carlisle, Pennsylvania

32997
Bourns Inc.
Trimpot Products Division
Riverside, California

33173
General Electric Co.
Products Dept.
Owensboro, Kentucky

Table 7-2. FEDERAL SUPPLY CODES FOR MANUFACTURERS (Continued)

34333
Silicon General
Westminister, California

34335
Advanced Micro Devices
Sunnyvale, California

34802
Electromotive Inc.
Kenilworth, New Jersey

37942
Mallory, P.R. & Co., Inc.
Indianapolis, Indiana

42498
National Radio
Melrose, Massachusetts

43543
Nytronics Inc.
Transformer Co. Div.
Geneva, New York

44655
Ohmite Mfg. Co.
Skokie, Illinois

49671
RCA Corp.
New York, New York

49956
Raytheon Company
Lexington, Massachusetts

50088
Mostek Corp.
Carrollton, Texas

50579
Litronix Inc.
Cupertino, California

51605
Scientific Components Inc.
Linden, New Jersey

53021
Sangamo Electric Co.
Springfield, Illinois

54294
Cutler-Hammer Inc. formerly
Shallcross, A Cutter-Hammer Co.
Selma, North Carolina

55026
Simpson Electric Co.
Div. of Am. Gage and Mach. Co.
Elgin, Illinois

56289
Sprague Electric Co.
North Adams, Massachusetts

58474
Superior Electric Co.
Bristol, Connecticut

60399
Torin Corp, formerly
Torrington Mfg. Co.
Torrington, Connecticut

63743
Ward Leonard Electric Co., Inc.
Mount Vernon, New York

64834
West Mfg. Co.
San Francisco, Californai

65092
Weston Instruments Inc.
Newark, New Jersey

66150
Winslow Tele-Tronics Inc.
Eaton Town, New Jersey

70485
Atlantic India Rubber Works
Chicago, Illinois

70563
Amperite Company
Union City, New Jersey

70903
Belden Corp.
Geneva, Illinois

71002
Birnbach Radio Co., Inc.
Freeport, LI New York

71400
Bussmann Mfg.
Div. of McGraw-Edison Co.
Saint Louis, Missouri

71450
CTS Corp.
Elkhart, Indiana

71468
ITT Cannon Electric Inc.
Santa Ana, California

71482
Clare, C.P. & Co.
Chicago, Illinois

71590
Centrelab Electronics
Div. of Globe Union Inc.
Milwaukee, Wisconsin

71707
Coto Coil Co., Inc.
Providence, Rhode Island

71744
Chicago Miniature Lamp Works
Chicago, Illinois

71785
TRW Electronics Components
Cinch Connector Operations Div.
Elk Grove Village, Chicago, Illinois

72005
Driver, Wilber B., Co.
Newark, New Jersey

72092
Replaced by 06980

72136
Electro Motive Mfg. Co.
Williamantic, Connecticut

72259
Nytronics Inc.
Pelham Manor, New Jersey

72619
Dialight Div.
Amperex Electronic Corp.
Brooklyn, New York

72653
G.C. Electronics
Div. of Hydrometals, Inc.
Brooklyn, New York

72665
Replaced by 90303

72794
Dzus Fastener Co., Inc.
West Islip, New York

72928
Gulton Ind. Inc.
Gudeman Div.
Chicago, Illinois

72982
Erie Tech. Products Inc.
Erie, Pennsylvania

73138
Beckman Instruments Inc.
Helipot Division
Fullerton, California

73293
Hughes Aircraft Co.
Electron Dynamics Div.
Torrence, California

73445
Amperex Electronic Corp.
Hicksville, LI, New York

73559
Carling Electric Inc.
West Hartford, Connecticut

73586
Circle F Industries
Trenton, New Jersey

73734
Federal Screw Products, Inc.
Chicago, Illinois

73743
Fischer Special Mfg. Co.
Cincinnati, Ohio

73899
JFD Electronics Co.
Components Corp
Brooklyn, New York

73949
Guardian Electric Mfg. Co.
Chicago, Illinois

74199
Quan Nichols Co.
Chicago, Illinois

74217
Radio Switch Corp.
Marlboro, New Jersey

74276
Signalite Div.
General Instrument Corp.
Neptune, New Jersey

74306
Piezo Crystal Co.
Carlisle, Pennsylvania

74542
Hoyt Elect. Instr. Works
Penacook, New Hampshire

74970
Johnson E.F., Co.
Waseca, Minnesota

75042
TRW Electronics Components
IRC Fixed Resistors
Philadelphia, Pennsylvania

75376
Kurz-Kasch Inc.
Dayton, Ohio

75378
CTS Knights Inc.
Sandwich, Illinois

75382
Kulka Electric Corp.
Mount Vernon, New York

75915
Littlefuse Inc.
Des Plaines, Illinois

76854
Oak Industries Inc.
Switch Div.
Crystal Lake, Illinois

77342
AMF Inc.
Potter & Brumfield Div.
Princeton, Indiana

77638
General Instrument Corp.
Rectifier Division
Brooklyn, New York

77969
Rubbercraft Corp. of CA. LTD.
Torrance, California

78189
Shakeproof
Div. of Illinois Tool Works Inc.
Elgin, Illinois

78277
Sigma Instruments, Inc.
South Braintree, Massachusetts

78488
Stackpole Carbon Co.
Saint Marys, Pennsylvania

78553
Eaton Corp. Engineered
Fastener Div.
Tinnerman Plant
Cleveland, Ohio

79136
Waldes Kohinoor Inc.
Long Island City, New York

79497
Western Rubber Company
Goshen, Indiana

79963
Zierick Mfg. Corp.
Mt. Kisko, New York

80031
Electro-Midland Corp., Mepco Div.
A North American Phillips Co.
Morristown, New Jersey

80145
LFE Corp., Process Control Div.
formerly API Instrument Co.
Chesterland, Ohio

80183 - use 56289
Sprague Products
North Adams, Massachusetts

80294
Bourns Inc., Instrument Div.
Riverside, California

80583
Hammarlund Mfg. Co., Inc.
Red Bank, New Jersey

80640
Stevens, Arnold Inc.
South Boston, Massachusetts

81073
Grayhill, Inc.
La Grange, Illinois

81312
Winchester Electronics
Div. of Litton Industries Inc.
Oakville, Connecticut

81439
Therm-O-Disc Inc.
Mansfield, Ohio

81483
International Rectifier Corp.
Los Angeles, California

81590
Korry Mfg. Co.
Seattle, Washington

81741
Chicago Lock Co.
Chicago, Illinois

82305
Palmer Electronics Corp.
South Gate, California

82389
Switchcraft Inc.
Chicago, Illinois

Table 7-2. FEDERAL SUPPLY CODES FOR MANUFACTURERS (Continued)

82415
North American Phillips
Controls Corp.
Frederick, Maryland

82872
Roanwell Corp.
New York, New York

82877
Rotron Inc.
Woodstock, New York

82879
ITT Royal Electric Div.
Pawtucket, Rhode Island

83003
Varo Inc.
Garland, Texas

83058
Carr Co., The United Can Div.
of TRW
Cambridge, Massachusetts

83298
Bendix Corp.
Electric Power Division
Eatontown, New Jersey

83330
Smith, Herman H., Inc.
Brooklyn, New York

83478
Rubbercraft Corp. of America, Inc.
West Haven, Connecticut

83594
Burroughs Corp.
Electronic Components Div.
Plainfield, New Jersey

83740
Union Carbide Corp.
Battery Products Div.
formerly Consumer Products Div.
New York, New York

84171
Arco Electronics
Great Neck, New York

84411
TRW Electronic Components
TRW Capacitors
Ogallala, Nebraska

84613
Fuse Indicator Corp.
Rockville, Maryland

84682
Essex International Inc.
Industrial Wire Div.
Peabody, Massachusetts

86577
Precision Metal Products,
of Malden Inc.
Stoneham, Massachusetts

86684
Radio Corp. of America
Electronic Components Div.
Harrison, New Jersey

86928
Seastrom Mfg. Co., Inc.
Glendale, California

87034
Illuminated Products Inc.
Subsidiary of Oak Industries Inc.
Anahiem, California

88219
Gould Inc.
Industrial Div.
Trenton, New Jersey

88245
Litton Systems Inc.
Useco Div.
Van Nuys, California

88419
Cornell-Dubilier Electronic Div.
Federal Pacific Co.
Fuquay-Varian, North Carolina

88486
Plastic Wire & Cable
Jewitt City, Connecticut

88690
Replaced by 04217

89536
Fluke, John Mfg. Co., Inc.
Seattle, Washington

89730
G.E. Co., Newark Lamp Works
Newark, New Jersey

90201
Mallory Capacitor Co. Div of
P.R. Mallory Co., Inc.
Indianapolis, Indiana

90211 - use 56365
Square D Co.
Chicago, Illinois

90215
Best Stamp & Mfg. Co.
Kansas City, Missouri

90303
Mallory Battery Co.
Div. of Mallory Co., Inc.
Tarrytown, New York

91094
Essex International Inc.
Suglex/IWP Div.
Newmarket, New Hampshire

91293
Johanson Mfg. Co.
Boonton, New Jersey

91407
Replaced by 58474

91502
Associated Machine
Santa Clara, California

91506
Augat Inc.
Attleboro, Massachusetts

91637
Dale Electronics Inc.
Columbus, Nebraska

91662
Elco Corp.
Willow Grove, Pennsylvania

91737 - use 71468
Gremar Mfg. Co., Inc.
ITT Cannon/Gremar
Santa Ana, California

91802
Industrial Devices, Inc.
Edgewater, New Jersey

91833
Keystone Electronics Corp.
New York, New York

91836
King's Electronics Co., Inc.
Tuckahoe, New York

91929
Honeywell Inc.
Micro Switch Div.
Freeport, Illinois

91934
Miller Electric Co., Inc.
Div of Aunet
Woonsocket, Rhode Island

92194
Alpha Wire Corp.
Elizabeth, New Jersey

93332
Sylvania Electric Products
Semiconductor Products Div.
Woburn, Massachusetts

94145
Replaced by 49956

94154 - use 94988
Wagner Electric Corp.
Tung-Sol Div.
Newark, New Jersey

94222
Southco Inc. formerly
South Chester Corp.
Lester, Pennsylvania

95146
Alco Electronic Products Inc.
Lawrence, Massachusetts

95263
Leecraft Mfg. Co.
Long Island City, New York

95264
Replaced by 98278

95275
Vitramon Inc.
Bridgeport, Connecticut

95303
RCA Corp.
Receiving Tube Div.
Cincinnati, Ohio

95348
Gordo's Corp.
Bloomfield, New Jersey

95354
Methode Mfg. Corp.
Rolling Meadows, Illinois

95712
Bendix Corp.
Electrical Components Div.
Microwave Devices Plant
Franklin, Indiana

95987
Weckesser Co. Inc.
Chicago, Illinois

96733
San Fernando Electric Mfg. Co.
San Fernando, California

96853
Gulton Industries Inc.
Measurement and Controls Div.
formerly Rustrak Instruments Co.
Manchester, New Hampshire

96881
Thomson Industries, Inc.
Manhasset, New York

97540
Master Mobile Mounts
Div. of Whitehall Electronics Corp.
Ft. Meyers, Florida

97913
Industrial Electronic Hdware Corp.
New York, New York

97945
Penwalt Corp.
SS White Industrial Products Div.
Piscataway, New Jersey

97966
Replaced by 11358

98094
Replaced by 49956

98159
Rubber-Teck, Inc.
Gardena, California

98278
Malco A Microdot Co., Inc.
Connector & Cable Div.
Pasadena, California

98291
Sealectro Corp.
Mamaroneck, New York

98388
Royal Industries
Products Div.
San Diego, California

98743
Replaced by 12749

98925
Replaced by 14433

99120
Plastic Capacitors, Inc.
Chicago, Illinois

99217
Bell Industries Elect. Comp. Div.
formerly Southern Elect. Div.
Burbank, California

99392
STM
Oakland, California

99515
ITT Jennings Monrovia Plant
Div. of ITT Jennings formerly
Marshall Industries Capacitor Div.
Monrovia, California

99779 - use 29587
Bunker-Ramo Corp.
Barnes Div.
Landsdowne, Pennsylvania

99800
American Precision Industries Inc.
Delevan Division
East Aurora, New York

99942
Centrelab Semiconductor
Centrelab Electronics Div. of
Globe-Union Inc.
El Monte, California

Toyo Electronics
(R-Ohm Corp.)
Irvine, California

National Connector
Minneapolis, Minnesota

Table 7-3. FLUKE TECHNICAL SERVICE CENTERS

John Fluke Mfg. Co., Inc.
7001 - 220th Ave. S. W.
Mountlake Terrace, WA 98043
Tel: 206-774-2206

Fluke Western Technical Center
2020 N. Lincoln St.
Burbank, CA. 91540
Tel: 213-849-4641

Fluke Western Technical Center
2359 De La Cruz Blvd.
Santa Clara, CA. 95050
Tel: 408-985-1200

Fluke Midwestern Technical Center
10800 Lyndale Ave. So.
Minneapolis, MN 55420
Tel: 612-884-4541

Fluke Midwestern Tech. Ctr.
1287 N. Rand Road
Des Plaines, IL 60016
Tel: 312-298-7470

Fluke Canadian Technical Ctr.
6427 Northam Drive
Mississauga, Ontario
Tel: 416-678-1500

Fluke Canadian Technical Centre
3829 - 12th St. N. E.
Calgary, Alberta T2E 6M5
Tel: 403-261-0780

Fluke Eastern Tech. Center
500 Union Blvd.
Totowa, NJ 07512
Tel: 201-742-3215

Fluke N. E. Tech. Ctr.
109 Massachusetts Ave.
Lexington, MA 02173
Tel: 617-861-8620

Fluke Mideastern Tech. Ctr.
11501 Huff Court
Kensington, MD. 20795
Tel: 301-881-5300

Fluke S. E. Technical Ctr.
P.O. Box 6578
940 N. Fern Creek Ave.
Orlando, FL 32803
Tel: 305-896-2296

Fluke S. E. Technical Center
P. O. Box 9619
1310 Beaman Place
Greensboro, NC 27408
Tel: 919-273-1918

Fluke Southwestern Tech. Ctr.
1980 S. Quebec St.
Unit 4
Denver, CO 80231
Tel: 303-750-1228

Table 7-4. INTERNATIONAL SERVICE CENTERS

Fluke (Nederland) B.V.
P.O. Box 5053
Zevenheuvelenweg 53
Tilburg, Netherlands
Tel: (13) 673973

Fluke International Corporation
Garnet Close
Watford, WD-2 4TT, England
Tel: 0923-33066

Coasin S. A.
Virrey del Pino 4071
Buenos Aires, Argentina
Tel: 523185

Elmeasco Instruments Pty Ltd.
P. O. Box 334
Brookvale, N.S.W.
Australia 2100
Tel: (02 939-7944

Ambriex S. A.
Rua Ceara, 104 - 2.° e 3.° Andares
ZC - 29
Rio de Janeiro GB, Brazil
Tel: 264-7406

Rua Tupi, 535
01233 Sao Paulo SP, Brazil
Tel: 52-7806 & 0912

Proteco Coasin CIA, Ltda.
Apartado 228A
Quito, Ecuador
Tel: 526759

M.B. Electronique S. A.
29, Rue Emile Duclaux
92150, Suresnes, France
Tel: 7723111 (108)

Gilman & Co., Ltd.
P. O. Box 56
Hong Kong
Tel: 227011 (14)

Hinditron Services Pvt Ltd.
69/ A.L. Jagmohandas Marg.
Bombay - 400 006, India
Tel: 365344

Berkeh Company Ltd.
20 Salm Raod, Roosevelt Ave.
Tehran, Iran
Tel: 828294 831564

R.D.T. Electronics Engineering Ltd.
46, Sokolov Street
Ramat Hasharon 47235 Isreal
Tel: 483211

Toyo Trading Company, Ltd.
P. O. Box 5014
International Tokyo
Tokyo 100-31, Japan
Tel: (03) 279-0771

Mexitek, S. A.
Eugenia 408
Department 1
Mexico 12, D.F.
Mexico
Tel: 5360910-5239751

C. N. Rood N. V.
13, Cort van der Lindenstraat
P. O. Box 42
Rijswijk ZH 2100
Netherlands
Tel: 070-996360

Morgenstierne & Co. A/S
Konghellgate 3
P.O. Box 6688, Rodelokka
Oslo 5, Norway
Tel: 472-356110

Brixton Trading Company, Inc.
Suite 36 Metropolitan Bank Bldg.
Ayala Avenue
Makati, Rizal D-708, Phillippines
Tel: 88-27-06, 88-58-90

Elairco (Pty) Ltd.
P. O. Box 13091
Benoni 1511
Transvaal
Republic of South Africa
Tel: 54-5513 - 547571

Coasin C. A.
Apdo, Postal 50939
Sabana Grande No. 1
Caracas 105, Venezuela
Tel: 722311 - 728662

Table 7-5. SALES REPRESENTATIVES - DOMESTIC

ALABAMA

HUNTSVILLE
BCS Associates, INc.
3322 S. Memorial Parkway
P.O. Box 1273
Tel. (205) 881-6220
Zip 35807

ALASKA

ANCHORAGE
Harry Lang & Associates
1406 W. 47th Ave.
Tel. (907) 279-5741
Zip 99503

ARIZONA

PHOENIX
Barnhill Associates
7319 E. Stetson Dr.
Tel. (602) 947-7841
Scottsdale, AZ 85251

CALIFORNIA

LOS ANGELES
Instrument Specialists, Inc.
2020 N. Lincoln Street
Burbank, CA 91504
Tel. (213) 849-7181

NEWPORT BEACH
Instrument Specialists, Inc.
4120 Birch Street
Suite 119
Tel. (714) 752-6200
Zip 92660

SANTA CLARA
Instruments Specialists, Inc.
2359 De La Cruz Blvd.
Tel. (408) 244-1505
Zip 95050

COLORADO

DENVER
Barnhill Associates, Inc.
1980 South Quebec St. Unit 4
Tel. (303) 750-1222
Zip 80231

CONNECTICUT

HARTFORD
Instrument Representatives, Inc.
P. O. Box 518
Glastonbury, CT 06033
Tel. (203) 633-0777

FLORIDA

ORLANDO
BCS Associates, Inc.
940 N. Fern Creek Ave.
Tel. (305) 896-4881
Zip 32803

GEORGIA

DECATUR
BCS Associates, Inc.
2522 Tanglewood Road
Tel. (404) 321-0980
Zip 30033

HAWAII

HONOLULU
Industrial Electronics, Inc.
646 Queen Street
P. O. Box 135
Tel. (808)533-6095
Zip 96817

ILLINOIS

CHICAGO
Cozzens & Cudahy, Inc.
1301 N. Rand Road
Des Plaines, IL 60016
Tel. (312) 298-3600

INDIANA

INDIANAPOLIS
Cozzens & Cudahy, Inc.
Port O'Call Executive Ctr.
21 Beachway Drive
Tel:(317) 244-2456
Zip: 46224

KENTUCKY

VALLEY STATION
BCS Associates, Inc.
4506 Freda Way
Tel: (502) 935-9634
Zip: 40272

MARYLAND

BALTIMORE
Electronic Marketing Assoc. Inc.
11501 Huff Court
Kensington, MD 20795
Tel: (301) 881-5300, 744-7700

MASSACHUSETTS

BOSTON
Instrument Representatives, Inc.
109 Massachusetts Ave.
Lexington, MA 02173
Tel. (617) 861-8620

MICHIGAN

DETROIT
WKM Associates, Inc.
345 Girard
Madison Hts, MI, 48071
Tel: (313) 588-2300

MINNESOTA

MINNEAPOLIS
Cozzens & Cudahy, Inc.
10800 Lyndale Ave. S. 55420
Tel: (612) 884-4336

MISSOURI

KANSAS CITY
Cozzens & Cudahy, Inc.
4404 Chouteau Traffic Way
Tel. (816) 454-5836
Zip 64117

ST. LOUIS
Cozzens & Cudahy Inc.
P. O. Box 10013
Lambert Field - Zip 63145
Tel: (314) 423-1234

NEW JERSEY

NEWARK
SBM Representatives
1519A Stuyvesant Avenue
Union, NJ 07083
Tel: (201) 687-8737

NEW MEXICO

ALBUQUERQUE
Barnhill Associates
1410 - D Wyoming N. E.
Tel (505) 299-7658
Zip: 87112

NEW YORK

NEW YORK
SBM Representatives
28 Hobby Street
Pleasantville, NY 10570
Tel (914) 769-1811

ROCHESTER
SBM Representatives
4515 Culver Road
Tel. (716) 226-1400
Zip 14622

NORTH CAROLINA

GREENSBORO
BCS Associates, Inc.
P.O. Box 9619
1310 Beaman Place
Tel. (919) 273-1918
Zip 27408

OHIO

CLEVELAND
WKM Associates, Inc.
16141 Puritas Ave.
Tel. (216) 267-0445
Zip 44135

DAYTON
WKM Associates, Inc.
7913 So. Suburban Road
Tel. (513) 434-7500
Zip: 45459

Table 7-5. SALES REPRESENTATIVES - DOMESTIC (Continued)

OREGON

BEAVERTON
Showalter Instruments, Inc.
3800 S.W. Cedar Hills Blvd.
Suite 160
Tel: (503) 646-5196
Zip 97005

PENNSYLVANIA

PHILADELPHIA
Electronic Marketing Assoc.
210 Goddard Blvd. Ste. 100
King of Prussia, PA
Tel. (215) 248-5050
Zip 19406

PITTSBURGH
WKM Associates, Inc.
90 Clairton Blvd.
Tel. (412) 892-2953
Zip 15236

TEXAS

DALLAS
Barnhill Associates
908 Business Parkway
Richardson, TX 75080
Tel. (214) 231-2573

HOUSTON
Barnhill Associates
10606 Hempstead Hwy.
Suite 132
Tel. (713) 688-9971
Zip 77092

VIRGINIA

WILLIAMSBURG
BCS Associates
107 Rich Neck Road
Tel. (804) 877-4053
Zip: 23185

WASHINGTON

SEATTLE
Showalter Instruments, Inc.
1521 - 130 N. E.
Bellevue, WA 98005
Tel. (206) 455-4922
(206) 624-4035

CANADA

BRITISH COLUMBIA

NORTH VANCOUVER
Allan Crawford Associates, Ltd.
116 E. 3rd St. Suite 203
Tel: (604) 980-4831

ALBERTA

CALGARY
Allan Crawford Associates, Ltd.
3829 - 12th St. N. E. T2E 6M5
Tel. (403) 276-9658

ONTARIO

MISSISSAUGA
Allan Crawford Associates, Ltd.
6427 Northern Drive
Tel. (416) 678-1500

OTTAWA, 3
Allan Crawford Associates, Ltd.
1299 Richmond Road K2B 7Y4
Tel. (613) 829-9651

QUEBEC

LONGUEUIL
Allan Crawford Associates, Ltd.
1330 Marie Victorian Blvd. East
Longueuil Br. P.Q. J4G 1A2
Tel (514) 670-1212

NOVA SCOTIA

DARTMOUTH
Allan Crawford Associates, Ltd.
St. 201, Townsend Pl.
800 Windmill Rd.
Burnside Industrial Park
Dartmouth, N. S. B3B 1L1
Tel (902) 469-7865

Table 7-6. SALES REPRESENTATIVES – INTERNATIONAL

Argentina
Coasin S.A.
Virrey del Pino 4071
Buenos Aires, Argentina
Tel: 523185

Austria
Kontron GmbH & Co. KG.
Ameisgasse 49
1140 - Vienna, Austria
Tel: 09-43222945646

Australia
Elmeasco Instruments, Pty Ltd.
P.O. Box 334
Brookvale, N.S.W.
Australia 2100
Tel: (02) 939-7944

Belgium
C.N. Rood S.A.
37, Place de Jamblinee de Meux
B-1040 Brussels, Belgium
Tel: 02-27352135

Brazil
Ambriex S.A.
Rua Ceara, 104 - 2°. e 3°. Andares
ZC-29
Rio de Janeiro GB, Brazil
Tel: 264-7406

Ambriex S. A.
Rua Tupi, 535
01233 Sao Paulo SP, Braxil
Tel: 52-7806 & 0912

Caribbean
West Indies Sales Co., Ltd.
7360 N. W. 66th St.
Miami, FL 33166
Tel: (305) 592-8188

Central America
Intermetra Corp
11 Park Place, Suite 2003
New York, NY 10007
Tel (212) 349-7630, 31, 32

Chile
Coasin Chile Ltd.
Casilla 14588 - Correo 15
Santiago, Chile
Tel: 396713

China
May Lee Industries, Inc.
111 Broadway, Suite 510
New York, NY 10006
Tel: (212) 349-5780

Columbia
Asistec Limitada
Apartado Aereo 12322
Bogota 1, Colombia
Tel: 419331

Cyprus
Chris Radiovision Ltd.
P. O. Box 1989
Nicosia, Cyprus
Tel: 66121

Denmark
Tage Olsen A/S
Teglvaerksgade 37
DK-2100 Copenhagen 0
Denmark
Tel: 01-294800

Eastern Europe Countries
Elpro GmbH
Molkergasse 4
1080 - Vienna, Austria
Tel: 222 424692

Ecuador
Proteco Coasin CIA, Ltda.
Apartado 228A
Quito, Ecuador
Tel: 526759

Egypt
Lotus Engineering Organisation
P. O. Box 1252
Cairo, Egypt
Tel: 71617

Table 7-6. SALES REPRESENTATIVES — INTERNATIONAL (Continued)

Finland
OY Findip AB
Teollisuustie 7
02700 Kaunianen
Finland
Tel: 502255

France
M.B. Electronique S.A.
29,Rue Emile Duclaux
92150, Suresnes France
Tel: 7723411 (108)

Germany
Fluke (Deutschland) GmbH
4-Dusseldorf
Meineckestrasse 53
West Germany
Tel: 450831

Greece
Hellenic Scientific Representations Ltd.
10, Nympheau Street
Athens 615 Greece
Tel: 7792320/705960

Hong Kong & Macao
Gilman & Co., Ltd.
P.O. Box 56
Hong Kong
Tel: 227011 (14)

India
Hinditron Services Pvt. Ltd.
69/A. L. Jagmohandas Marg
Bombay - 400 006, India
Tel: 365344

Indonesia
P.T. United Dico-Citas Co., Ltd.
JLN Penjaringan 39A
Jakarta, Indonesia

Iran
Berkeh Company Ltd.
20 Salm Road. Roosevelt Ave.
Tehran, Iran
Tel: 828294 831564

Isreal
R.D.T. Electronics Engineering Ltd.
46, Sokolov St
Ramat Hasharon 47235 Isreal
Tel: 483211

Italy
Sistrel, S. p.A.
Via Giorgio da Sebenico 11-13
00143 Roma, Italy
Tel: 06-500-1860

Japan
Toyo Trading Company, Ltd.
P.O. Box 5014
International Tokyo
Tokyo 100-31, Japan
Tel: (03) 279-0771

Toyo Trading Company, Ltd.
Suzuki Bldg.
2-38 Junkeicho-dori
Minami-ku, Osaka, Japan
Tel: (06) 262-3471

Kenya
Advanced Communications, Ltd.
City House, Wabera Street
P.O. Box 30635
Nairobi, Kenya
Tel: 31955

Korea
Asia Science & Co.
International P. O. Box 1250
Seoul, Korea
Tel: 76-2761

Kuwait
Tareq Company
P.O. Box Safat 20506
Kuwait, Arabian Gulf
Tel: 436100, 436045

Lebanon
General Marketing Trading &
Contracting Company
Anis Nsouli Street
Nsouli Building
P.O. Box 155.655
Beirut, LEbanon
Tel: 319383, 312061

Malaysia
O'Connor's (PTE) Limited
P.O. Box 91
Petaling Jaya, Selangor
West Malaysia
Tel: 51563

Mexico
Mexitek, S.A.
Eugenia 408
Department 1
Mexico 12, D.F.
Mexico
Tel: 5360910 - 5239751

Morocco
S.I.E.E.M.
Residence Moulay Ismail
Bat. C.
Boulevard Moulay Slimane
Rabat, Morocco
Tel: 276-64

Netherlands
C N. Rood B.V.
13, Cort van der Lindenstraat
P.O. Box 42
Rijswijk ZH 2100
Netherlands
Tel: 070-996360

Fluke (Nederland) B.V.
P.O. Box 5053
Zevenheuvelenweg 53
Tilburg, Netherlands
Tel: (13) 673973

New Zealand
Elmeasco Instruments Pty Ltd.
P.O. Box 30515
LOWER HUTT
New Zealand
Tel: 697566

Nigeria
Deemtee Electrotechnics, Ltd.
P.O. Box 3073
Lagos, Nigeria

Norway
Morgenstierne & Co. A/S
Konghellegate 3
P.O. Box 6688, Rodelokka
Oslo 5, Norway
Tel: (02) 372940

Pakistan
Pak International Operations
505 Muhammadi House - McLeod Rd.
P.O. Box 5323
Karachi, Pakistan

Peru
Importaciones Y Representaciones
Electronicas S. A.
Avda, Franklin D. Roosevelt 105
Lima 1, Peru
Tel: 27-2078

Phillippines
Brixton Trading Company, Inc.
Suite 636 Metropolitan Bank Bldg.
Ayala Avenue
Makati, Rizal D-708, Phillippines
Tel: 88-27-06, 88-58-90

Portugal
Equipamentos De Laboratorio Lda.
P.O. Box 1100
Lisbon 1, Portugal
Tel: 976551

Singapore
O'Connor's (PTE) Limited
98 Pasir Panjang Road
Singapore 5, Singapore
Tel: 637944

Table 7-6. SALES REPRESENTATIVES – INTERNATIONAL (Continued)

South Africa
Elairco (Pty) Ltd.
P.O. Box 13091
Benoni 1511
Transvaal
Republic of South Africa
Tel: 54-5513 - 547571

Spain
Ataio Ingenieros S. A.
Enrique Larreta 12
Madrid 16, Spain
Tel: 7330562

Sweden
Teleinstrument AB
P.O. Box 490
Maltesholmvagen 490
S-162 04 Vallingby
Sweden
Tel: 08-380379

Switzerland
Kontron Electronic A.G.
Bernerstrasse-Sub 169
8048 Zurich. **Switzerland**
Tel:01-628282

Taiwan
Heighten Trading Co, Ltd.
P.O. Box 1408
Taipei, Taiwan 100
Republic of China
Tel: 5118324 - 5118372

Thailand
Dynamic Supply Engineering R.O.P.
No. 56 Ekamai, Sukhumvit 63
Bangkok 11, Thailand
Tel: 914434, 928532

Turkey
M. Suheyl Erkman
Necatibey Cad. 92/2
Karakoy/Istanbul
Turkey
Tel: 441546 - 447651

The United Kingdom
Fluke International Corporation
Garnet Close
Watford, WD 2 4 TT
England
Tel: 0923-33066

U. S. S. R.
Codevintec Pacific Inc.
6263 Variel
Woodland Hills, CA 91364
Tel: (213) 348-1719

Uruguay
Coasin,Uruguaya S. R. L.
Cerrito 617 - 4° Piso
Montevideo, Uruguay

Venezuela
Coasin C. A.
Apdo, Postal 50939
Sabana Grande No. 1
Caracas 105, Venezuela
Tel: 722311 - 728662

In Europe, contact FLUKE NEDERLAND, B.V., P.O. Box 5053, Industrieterrein Noord, Tilburg, The Netherlands.....

FLUKE REGIONAL SERVICE CENTER: The NETHERLANDS
FLUKE (NEDERLAND) B.V.
P.O. BOX 5053
TILBURG, THE NETHERLANDS

FLUKE REGIONAL SERVICE CENTER, UNITED KINGDOM
FLUKE INTERNATIONAL CORP.
GARNETT CLOSE
WATFORD, WD24TT ENGLAND.

AUTHORIZED SERVICE LABORATORIES INTERNATIONAL

EACH INTERNATIONAL REPRESENTATIVE IS EQUIPPED WITH AN AUTHORIZED SERVICE LABORATORY, PLEASE REFER TO THE INTERNATIONAL REPRESENTATIVE LISTING FOR YOUR SERVICE NEEDS.

Section 8
Schematic Diagrams

FIGURE NO.	NAME	DRAWING NO.	PAGE
8-1	A1A1 Thermometer PCB Assembly	2160A-1010	8-2
8-2	A1A2 Display PCB Assembly	2160A-1020	8-4
8-3	A2 Type Select PCB Assembly	2160A-1012	8-6

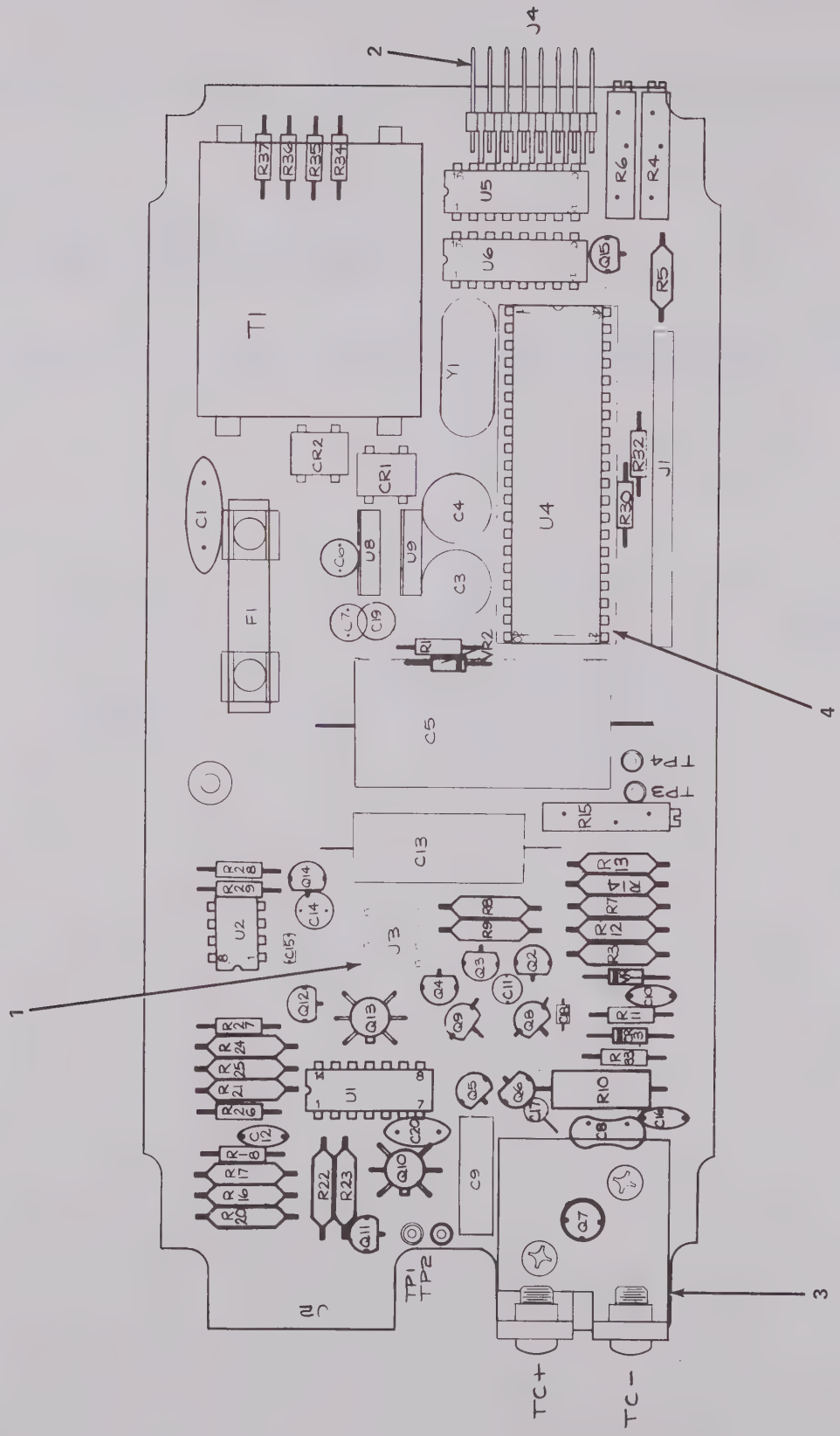


FIGURE 8-1. (1 of 2) A1A1 THERMOMETER PCB ASSEMBLY (2160A-1010)

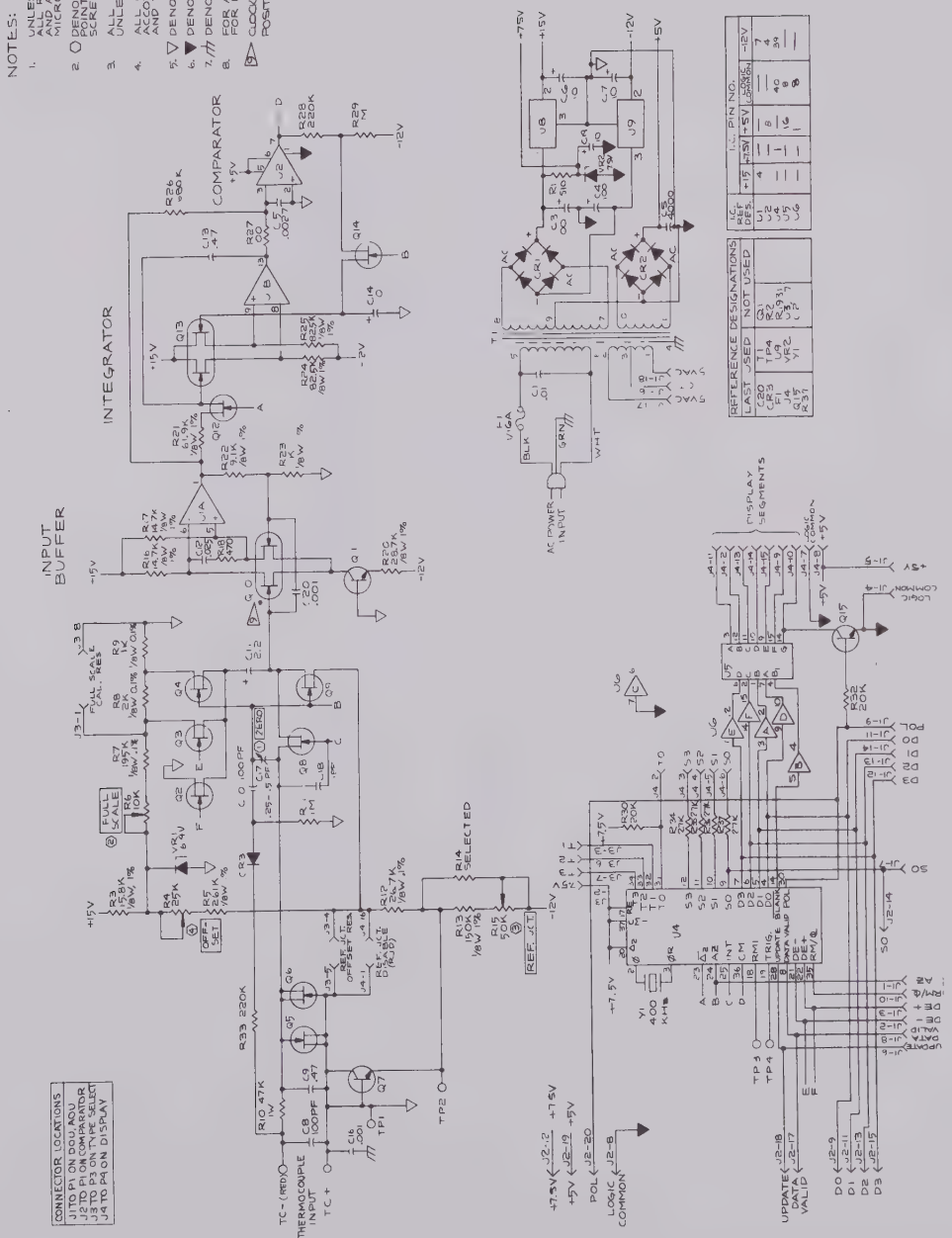

NOTES:
1. UNLESS OTHERWISE SPECIFIED ALL RESISTANCES ARE IN OHMS AND ALL CAPACITANCES ARE IN MICROFARADS.
2. ○ DENOTES CALIBRATION ADJUST POINTS ARE SCREW DRIVER ADJUST.
3. ALL RESISTORS ARE 1/4W, 5% UNLESS OTHERWISE SPECIFIED.
4. ALL GRAPHIC SYMBOLS IN ACCORDANCE WITH ANSI Y32.2 AND Y32.14.
5. ▽ DENOTES ANALOG COMMON.
6. ▼ DENOTES LOGIC COMMON.
7. DENOTES CHASSIS COMMON.
8. FOR ASSY DWG SEE 2160A-1010. FOR REF DES DWG SEE 2160A-1610.
9. CLOCK GO WITH MARKED GATE IN POSITION SHOWN.
INPUT BUFFER
INTEGRATOR
COMPARATOR
AC POWER INPUT
DISPLAY SEGMENTS
REFERENCE DESIGNATIONS
CONNECTOR LOCATIONS
THERMOCOUPLE INPUT
LOGIC COMMON
REF. SET
FULL SCALE
OFF-SET

FIGURE 8-1. (2 of 2) A1A1 THERMOMETER PCB ASSEMBLY (2160A-1010)

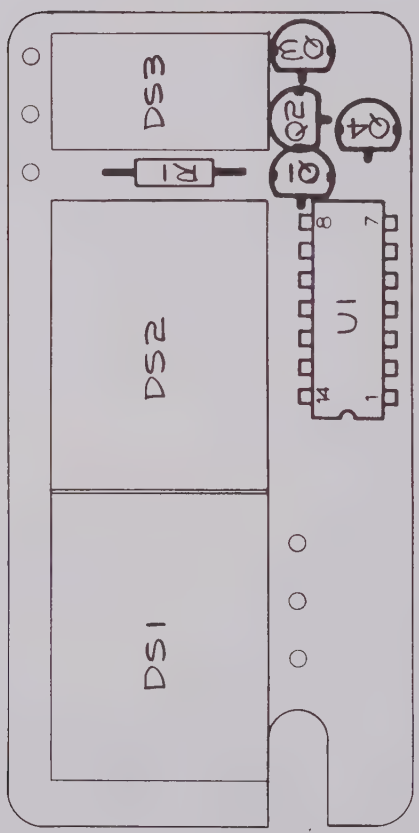


FIGURE 8-2. (1 of 2) A1A2 DISPLAY PCB ASSEMBLY (2160A-1020)

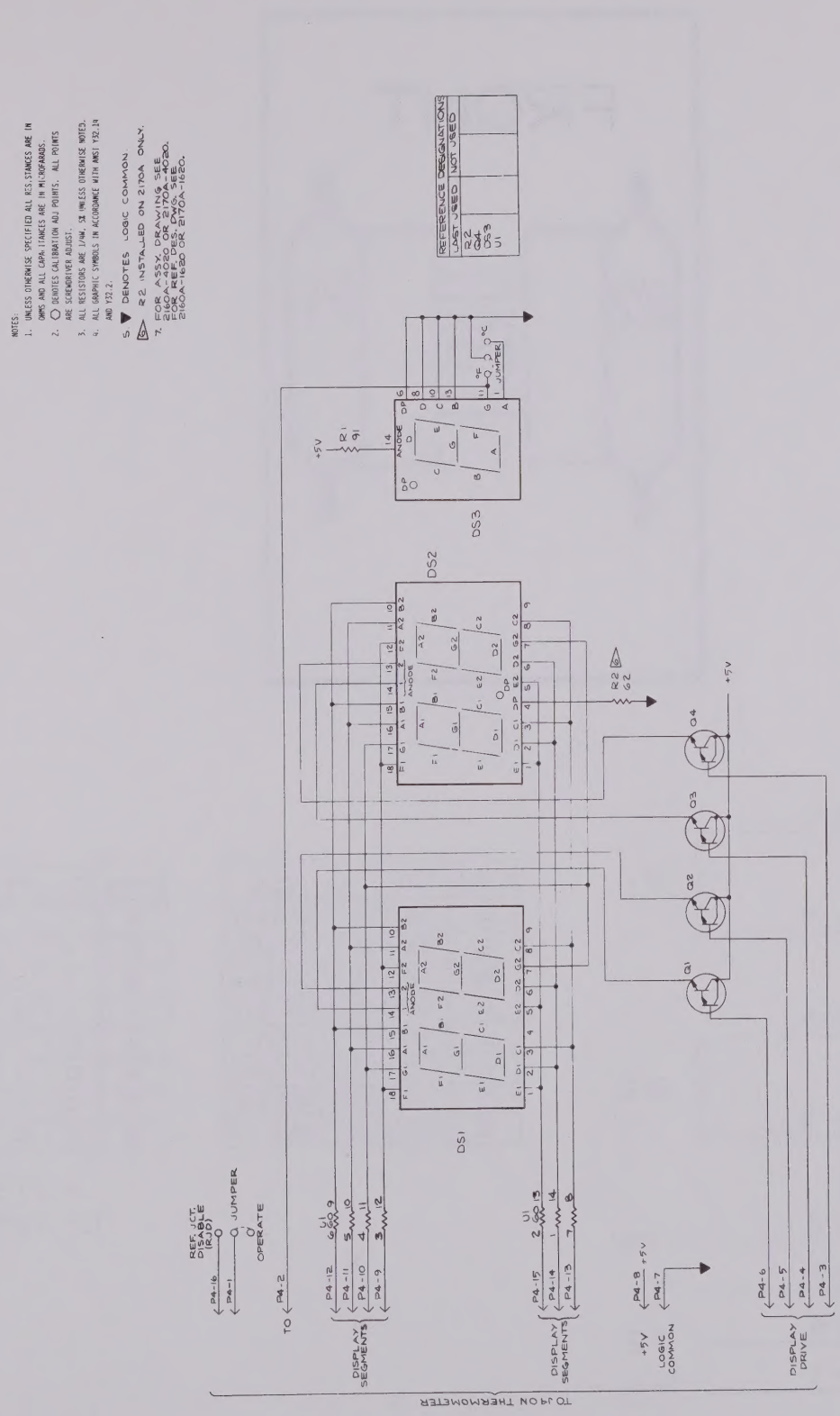
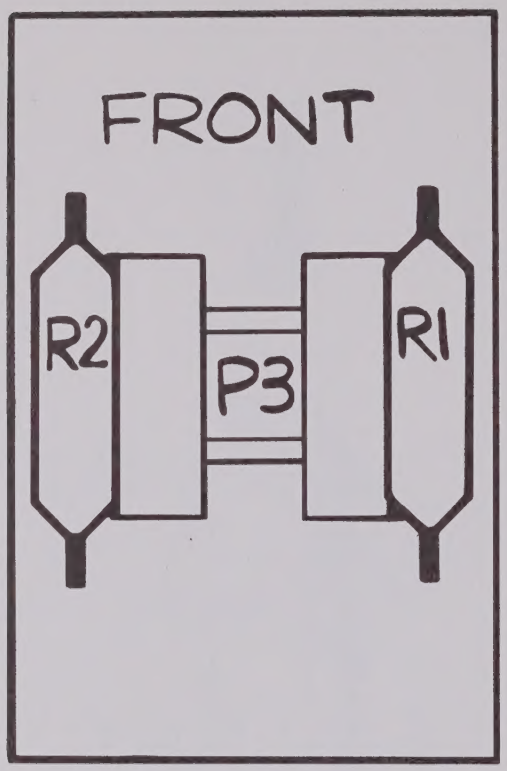
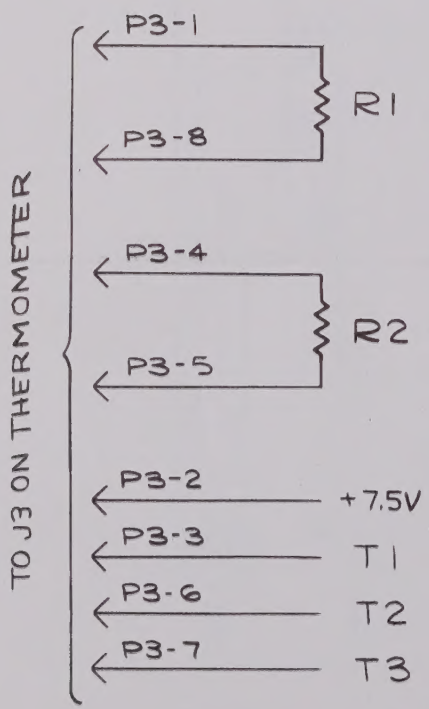


FIGURE 8-2. (2 of 2) A1A2 DISPLAY PCB ASSEMBLY (2160A-1020)





TYPE	R1	R2
R	324Ω	69.5Ω
S	324Ω	70.0Ω
B	143Ω	JUMPER
C	634Ω	123.5Ω
J	10.7K	619Ω
K	3.74K	481.4Ω
T	3.74K	483.7Ω
E	53.6K	732Ω

TYPE	T1	T2	T3
R	1	1	1
S	1	1	0
B	1	0	1
C	1	0	0
J	0	1	1
K	0	1	0
T	0	0	1
E	0	0	0

1 = +7.5V
0 = OPEN

FIGURE 8-3. A2 TYPE SELECT PCB ASSEMBLY (2160A-1012)